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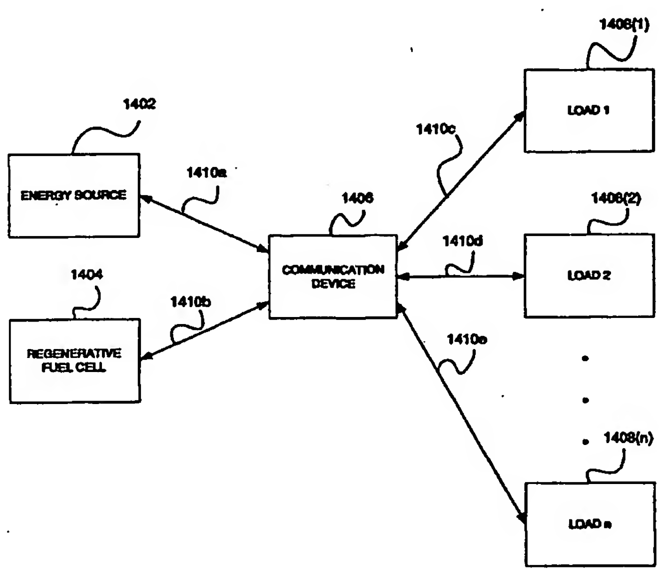

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(57) Abstract: A system and method for power mangement is described that provides for monitoring and controlling a regenerative fuel cell and at least one power device. The power management system includes a communication interface to faciliate data transmisson, a communication device for monitoring and controlling a regenerative fuel cell and at least one powered device, the communication device providing for sending data to the receiving data from at least one powered device over a communication interface, a regenerative fuel cell for providing storage and supply of electricity, and a power interface for allowing electricty generated by the regenerative fuel cell to power at least one powered device.

SYSTEM OF AND METHOD FOR POWER MANAGEMENT

This application is a continuation-in-part of U.S. Patent Application Serial No. 09/627,742, filed July 28, 2000, which is hereby fully incorporated by reference herein as though set forth in full.

FIELD OF THE INVENTION

The present invention relates generally to a system and method for power management in monitoring and controlling a regenerative fuel cell and at least one powered device, and is specifically concerned with a system and method providing for the power management system to communicate with a user and at least one powered device over a communication interface.

BACKGROUND OF THE INVENTION

The business world and our personal lives have become highly dependent on the communications industry. Technological advances have created the ability for individuals to access and control vast amounts of information from anywhere in the world using electronic devices such as computers and computer network systems. These electric consuming devices require a high level of reliable electricity along with minimal power interruptions. For example, in the industry of facilities automation management billions of dollars are spent each year on electricity delivered to homes, commercial facilities, industrial facilities, and on automated systems used for monitoring and controlling all aspects of these facilities. The automated systems can be highly sophisticated processing systems that require a steady, reliable supply of electricity.

The growth of technology has created one of the most important and fastest growing global problems because there is a growing gap between the reliability of the current electricity supply and the level of reliability actually needed by today's electric consuming devices. The reliability of electricity supply in the United States is currently dropping because demand is increasing faster than supply. The growth of the electric supply has been curtailed, in part, because of the uncertainty due to the electric industry

deregulation, increased environmental concerns, and opposition to new powerplants due to aesthetic reasons and the perceived health and safety risks.

Alternative methods of supplying reliable electricity are being evaluated such as distributed generation and energy storage. Distributed generation is the generation of electricity using many small generators scattered throughout a service territory. Distributed generation can be used to augment the local electricity supply without having to build additional large central-station powerplants.

Energy storage can significantly improve the electricity supply by storing energy at off-peak times for consumption during peak demand periods. This use of energy storage is often referred to as "load leveling" since it levels the power demand on the electric grid by the load. Load leveling is particularly useful when it is widely distributed and located at or near the point of electricity use, since it reduces the regional requirement for peak generating capacity and reduces the local requirements for transmission and distribution capacity. When energy storage is performed on the customer side of the electric meter, it is often called "peak shaving" rather than load leveling. Many structures and facilities in remote locations or in developing nations use energy storage in the form of non-electric grid renewable energy systems such as a wind energy collector or solar power. These non-electric grid systems require backup generators or another means of energy storage to provide electricity when the wind is not blowing or the sun is not shining.

Many electric consuming devices require premium, highly reliable power well beyond typical 99.9% electric grid power supplied in the United States. The demand for premium power has traditionally been served with backup power systems or uninterruptible power systems (UPSs). All backup power systems and UPSs include some form of energy storage, generation, or combination of both. In current state-of-the-art systems, lead-acid batteries are generally used for energy storage and generators running on gasoline, diesel fuel, propane, or natural gas are used for generation. Lead-acid batteries are generally used because they provide instantaneous energy and can handle most power outages, which are generally under 20 minutes in

duration. For power outages that are longer in duration, a generator can be configured to automatically supply electricity when needed.

There are several disadvantages in using lead-acid batteries for energy storage within a system including: (1) a limited energy storage capacity, (2) rapid deterioration when exposed to temperatures over 35°C, (3) rapid deterioration if discharged without frequent recharges, (4) inability to provide continuous power backup since they take many hours to recharge, (5) contain a large amount of lead that is toxic, (6) the energy contained in the batteries cannot be physically extracted for use in other devices, and (8) impractical for daily load leveling or peak shaving due to limited cycle life.

Some of the disadvantages in using lead-acid batteries can be overcome by combining them with a generator, which introduces other disadvantages including (1) noise and emission of poisonous gases, (2) not electrically rechargeable and reliant on fuel that goes bad after prolonged storage, (3) operates using highly flammable fuels that create a hazard to personnel and property, and (4) requires a relatively high level of maintenance.

A fuel cell can overcome most of the problems encountered with using lead-acid batteries, a generator, or a combination of both. A fuel cell provides the ability to generate reliable electricity and to deliver that energy on demand to powered devices. Fuel cells come in many different forms including zinc fuel cells and various types of hydrogen fuel cells such as phosphoric acid, proton exchange membrane (solid polymer), molten carbonate, solid oxide, and alkaline. Fuel cells generally produce electricity by electrochemically reacting a fuel and a reactant resulting in a reaction product. The fuel cells provide a clean and efficient energy source by producing zero emission electricity.

A fuel cell that has the added ability to regenerate or reuse reaction product is even more environmentally friendly. These fuel cells are often called "regenerative fuel cells" since the fuel cell includes hardware that can turn the reaction product back into fuel and reactant. This regenerative ability makes the regenerative fuel cell a perfect system to be used in remote locations, onboard a vehicle, and in facilities where it is inconvenient to periodically refuel the fuel cell.

Though still relatively undeveloped, regenerative fuel cells are now taking the form of hydrogen fuel cells and zinc fuel cells. A hydrogen regenerative fuel cell is configured for hydrogen and oxygen to be fed into the fuel cell. The resulting reaction results in the generation of electricity and a reaction product in the form of water. The water is recirculated back to a storage unit where it can later be regenerated back into hydrogen and oxygen. A zinc fuel cell is configured for zinc and oxygen to be fed into a fuel cell along with an electrolyte. The electrolyte is used as the transport medium for the zinc fuel, which is usually in the form of small particles. The resulting reaction results in the generation of electricity and a reaction product in the form of zinc oxide. The zinc oxide is recirculated back to a storage unit where it can later be regenerated back into zinc and oxygen.

The lack of significant energy storage capacity in the electric distribution system, combined with shrinking excess generating capacity, has caused and will continue to cause a reduction in the reliability of the electricity supply in the United States and developing nations, which have an even less reliable electric supply.

As the global community becomes more dependent on highly specialized electronic devices, the need for reliable electricity will increase along with the need to manage the supplied electricity. Power management in monitoring and controlling the electricity to these powered devices is essential in assuring that with increasing power loads the powered devices will have reliable power along with power backup when needed. Communication between the electric grid, the fuel cell, and powered devices is necessary to monitor and control operating conditions for reliable power.

As air pollution and rising fuel costs become increasingly important for operators of long-haul trucks and other vehicles, it is becoming more important for the operators of these vehicles to adopt new zero-emission technologies for powering auxiliary devices. For example, it is estimated by the US Department of Energy that the average long-haul heavy-duty truck spends up to $4,500 per year in fuel, repairs, and shortened engine life due to idling the truck's main engine to power auxiliary devices such as the television and air conditioner when the truck is parked. An on-board power management system incorporating a regenerative fuel cell could solve this problem.

For the reasons described above, there remains a need for a power management system that provides for monitoring and controlling a regenerative fuel cell and at least one powered device using energy storage for backup power, UPS, or load leveling/peak shaving applications, is electrically rechargeable or rapidly refuelable, and incorporates a method for communicating over an interface with a user, a regenerative fuel cell, and at least one powered device for sending and receiving data.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a power management system for supplying reliable electricity to be used for backup power, load leveling/peak shaving, supplying a regional electric grid, or powering electric consuming devices in a manner that is environmentally safe.

It is a further object of the present invention to provide a power management system with a regenerative fuel cell that is electrically rechargeable or rapidly refuelable by having a refillable fuel system utilizing refillable transportable containers.

It is still another object of the present invention to provide a power management system that monitors and controls a regenerative fuel cell and at least one powered device.

It is an object of the present invention to provide a power management system that provides for communication between a user, a regenerative fuel cell, and at least one powered device over a communication interface.

It is a further object of the present invention to provide a power management system that provides generated electricity to powered devices located onboard a vehicle and where the electricity is used to propel the vehicle or to power auxiliary devices onboard the vehicle.

It is still another object of the present invention to provide a power management system that is compact, efficient, and easy to use.

Additional objects include any of the foregoing objects, singly or in combination.

According to one aspect of the invention, a power management system is provided in which a communication device is configured to receive data from a source,

and then manage, responsive to the data, providing power from one or the other of an energy source and a regenerative fuel cell to one or more loads. The data may represent one or more rule or procedures, and the source of the data may be the energy source, one or more of the loads, the regenerative fuel cell, a user input device, or an external source such as an Internet site. The data may be stored in a memory.

In one implementation, the regenerative fuel cell is operatively engaged to provide power to the one or more loads during peak usage periods when power from the energy source is expensive, and the energy source is operatively engaged to provide power to the one or more loads during off-peak usage periods when power from the energy source is less expensive. In this example, time of day pricing information for driving this process may be obtained from the energy source, an external source such as an Internet site, or a user input device.

According to another aspect of the present invention, the power management system comprises a regenerative fuel cell and a communication interface configured to allow communication of data between the regenerative fuel cell and an external device, wherein the regenerative fuel cell is configured to deliver and receive power responsive to one or more parameters received from the external device over the interface.

The regenerative fuel cell comprises a fuel storage for storing fuel, a fuel cell for electrochemically reacting the fuel with a second reactant to release electricity, a reaction product storage for storing reaction product resulting from the reaction, a fuel regenerator for electrochemically recovering the fuel from the reaction product, and an optional second reactant storage unit. In some cases, the fuel cell itself may be used to regenerate the fuel. A communication device may be provided for monitoring and controlling the regenerative fuel cell, at least one powered device, and at least one energy source.

The power management system may further include a power interface, wherein electricity can be sent and received over the power interface; at least one energy source in communication with the communication device, the at least one energy source providing electricity to the regenerative fuel cell and at least one powered device, wherein the regenerative fuel cell can send electricity to and receive electricity

from the at least one energy source. The system may further include a user interface for exchanging data between a user and the regenerative fuel cell or device.

In another aspect of the present invention, a method for remotely controlling a regenerative fuel cell comprises the steps of inputting data over a user interface; providing the data to the regenerative fuel cell over a communication interface; and configuring the regenerative fuel cell to deliver power responsive to the data. The data comprises control parameters for the regenerative fuel cell.

In another aspect of the present invention, a method for monitoring at least one powered device comprises the steps of gathering data from at least one powered device; transmitting the data from at least one powered device to a regenerative fuel cell over a communication interface; and receiving and storing the data on a communication device in communication with the regenerative fuel cell. The data can be transmitted to a user. The data can be selected from the group comprising power usage information, environmental information, operating parameters, and control parameters.

The method for monitoring at least one powered device may further comprise the steps of comparing the data against preset control parameters supplied by a user; delivering power to the powered device responsive to the data; receiving the updated control parameters by at least one powered device; sending the updated control parameters from the powered device to other powered devices; and adjusting operation to perform within the updated control parameters.

In another aspect of the present invention, a method of power management for monitoring and controlling a regenerative fuel cell and at least one powered device through the use of a communication device comprises the steps of receiving power delivery requests; activating the regenerative fuel cell by commands from the communication device; electrochemically reacting a fuel and a second reactant; generating electricity and a reaction product from the reaction; and delivering the generated electricity.

RELATED PATENT APPLICATIONS AND PATENTS

This application is related to U.S. Patent No. 5,952,117 and U.S. Patent Application Serial Nos. 09/449,176; 09/521,392; and 09/353,422, all of which are owned in common by the assignee hereof, and all of which are fully incorporated by reference herein as though set forth in full.

BRIEF DESCRIPTION OF THE FIGURES

Understanding of the present invention will be facilitated by consideration of the following detailed description of exemplary embodiments of the present invention taken in conjunction with the accompanying drawings, in which like numerals refer to like part and in which:

Figure 1 is a block diagram of one embodiment of the present invention comprising a regenerative fuel cell and a communication device;

Figure 2 is a block diagram of an implementation of one embodiment of the present invention comprising a regenerative fuel cell, a communication device, an interface, and at least one powered device;

Figure 3 is a block diagram of an implementation of one embodiment of the present invention comprising a regenerative fuel cell, a communication device, an interface, at least one powered device, and at least one energy source;

Figure 4 is a block diagram of an implementation of one embodiment of the present invention comprising a regenerative fuel cell, a communication device, an interface, at least one powered device, and a user interface;

Figure 5 is a block diagram of an implementation of one embodiment of the present invention comprising a regenerative fuel cell, a communication device, an interface, at least one powered device, at least one energy source, and a user interface;

Figure 6 is a block diagram of an example implementation of the communication device configured as a computer;

Figure 7 is a block diagram of an example implementation of the regenerative fuel cell along with a communication device and an interface;

Figure 8 is a flow diagram of an example method of the present invention for remotely monitoring and controlling the regenerative fuel cell;

Figure 9 is a flow diagram of an example method of the present invention for a communication device to monitor and control at least one powered device;

Figure 10 is a flow diagram of an example method of the present invention for monitoring and controlling a regenerative fuel cell and at least one powered device through the use of a communication device, the communication device monitors for power delivery requests;

Figure 11 is a system block diagram showing the communication device and regenerative fuel cell having the ability to send data to and receive data from a plurality of example devices over the communication interface;

Figure 12 is a system block diagram showing the communication device and regenerative fuel cell having the ability to send power to a plurality of example devices over the power interface along with the ability to receive power from a plurality of example devices over the power interface; and

Figure 13 is a block diagram illustrating the operation processes of the power management system.

Figures 14A-14D are block diagrams of embodiments of power management systems according to the invention.

Figures 15A-15B are block diagrams of implementations of communications devices of power management systems according to the invention.

Figure 16 is a block diagram of an embodiment of a regenerative fuel cell system according to the invention.

Figure 17 is a flowchart of one embodiment of a method of operation according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

A first embodiment of a power management system in accordance with the subject invention is illustrated in Figure 1. The power management system of Figure 1 comprises a regenerative fuel cell 100 and a communication device 102.

In one implementation as illustrated in Figure 7, the regenerative fuel cell 100 comprises a fuel storage unit 702 for storing fuel, a fuel cell 700 for electrochemically reacting the fuel with a second reactant to release electricity, a reaction product storage unit 704 for storing reaction product resulting from the reaction, and a fuel regenerator 708 for electrochemically recovering the fuel from the reaction product. The fuel storage unit 702 can store a fuel that can be any material that releases electrical energy when reversibly combined electrochemically with a second reactant. For example, the fuel can be, but is not limited to, hydrogen or zinc.

A second reactant product storage unit 706 can optionally be included for storing the second reactant. The second reactant can be any substance that will react with the fuel for producing electricity. For example, the second reactant will generally be an oxidant such as, but not limited to, oxygen (either in pure form or in air from the atmosphere), peroxides, or halogens. The choice of a second reactant will depend on the choice of fuel used for a selected reaction. The regenerative fuel cell 100 may provide for at least one of the fuel storage unit 702, the fuel cell 700, or the reaction product storage unit 704 to simultaneously store an electrolyte. The electrolyte can be used in combination with the fuel and second reactant in the fuel cell 700 for contributing to the reaction for producing electricity. In some cases the electrolyte may also be used as a transport medium for moving fuel and reaction product in and out of the fuel cell and fuel regenerator.

The fuel regenerator 708 is used for the regeneration process of electrochemically reducing the fuel from its oxidized state and releasing the second reactant. The fuel regenerator 708 can be configured to use various methods for the regeneration process. The fuel regenerator 708 can be physically incorporated into the regenerative fuel cell 100 or can be physically separate from the regenerative fuel cell 100. Alternatively, the fuel regenerator 708 is the fuel cell 700.

In one implementation as illustrated in Figures 7 and 13, the fuel regenerator 708 is supplied electricity from at least one energy source 300 for the regeneration process. The reaction product is moved from the reaction product storage unit 704 into the fuel regenerator 708. The electrochemical reaction that takes place within the fuel

regenerator involves reducing the fuel from its oxidized state and releasing the second reactant. Once this reverse reaction has occurred, the fuel is moved into the fuel storage unit 702 and the second reactant is moved into the second reactant storage unit 706 or released to the environment.

In one implementation, the regenerative fuel cell 100 will include a system for inserting and removing quantities of fuel, reaction product, and second reactant. This system will provide the regenerative fuel cell 100 with ability to be rapidly refueled in a quick and efficient manner. For example, refueling can take place by removing reaction product and adding fuel. This can be accomplished using refillable transportable containers, hoses, or any other acceptable means. The fuel can be compressed hydrogen gas, liquid hydrogen, hydrogen stored in a metal hydride, zinc particles immersed in potassium hydroxide electrolyte, or any other acceptable fuel. Alternatively, the refueling procedure can also be used in reverse where fuel can be removed and stored for emergency use or to power other devices. The fuel is removed and replaced with an equivalent quantity of reaction product. The reaction product will be used for regeneration back into fuel and a second reactant.

In one implementation example, zinc is used as the fuel and oxygen as the second reactant. In this implementation example, the regenerative fuel cell 100 could include a second reactant storage for storing the oxygen. Alternatively, the oxygen can be obtained from the ambient air. The regenerative fuel cell 100 may have a small power source to provide initial startup power to a pump and a blower to move the fuel, the second reactant, and the electrolyte into the fuel cell 700. The power source can be a battery or other electricity source. Within the fuel cell 700 a reaction occurs resulting in the generation of electricity. The zinc is consumed and releases electrons to drive a load (the anodic part of the electrochemical process), and the oxygen accepts electrons from the load (the cathodic part). The reaction between the zinc and oxygen, mediated by the electrolyte, yields a reaction product of zinc oxide. The zinc oxide gets mixed or dissolved into the electrolyte and is then pumped into the reaction product storage unit 704 until regeneration is needed.

In another implementation example, hydrogen is used as the fuel and oxygen or air as the second reactant. In this implementation example, the regenerative fuel cell 100 can include a second reactant storage unit 706 for storing the oxygen. The regenerative fuel cell 100 has a small power source to provide initial startup power to a pump and a blower to move the fuel, the second reactant, and the electrolyte into the fuel cell 700. The power source can be a battery or other electric source.

Within the fuel cell 700 a reaction occurs resulting in the generation of electricity. The reaction between the hydrogen and oxygen, mediated by the electrolyte (which may be liquid or solid) yields a reaction product of water. The water is then pumped into the reaction product storage unit 704 until regeneration is needed. The regeneration process is initiated by circulating the water into the fuel regenerator 708 from the reaction product storage unit 704. The reaction product (water) is then electrochemically converted back into hydrogen and oxygen.

More detailed information on the regenerative fuel cell can be found in U.S. Pat. No. 5,952,117, U.S. Patent Application Serial Nos. 09/449,176; 09/521,392; and 09/353,422, each of the following references is hereby fully incorporated by reference herein as though set forth in full.

The communication device 102 has the capability of monitoring and controlling all components of the power management system including the regenerative fuel cell 100, at least one powered device 200, and at least one energy source 300. The communication device 102 can be any device that allows for data to be sent and received over a communication interface 712 as illustrated in Figures 2, 7, and 11. The communication device 102 can be incorporated into the physical structure of the regenerative fuel cell 100. Alternatively, the communication device 102 can be housed in a separate structure independent of the regenerative fuel cell 100, but is directly connected to the regenerative fuel cell 100.

The communication device 102 is at least one selected from the group comprising of a processor coupled to memory, a computer, laptop, handheld computer, PDA (Personal Digital Assistant), mainframe, server system, mobile phone, or any other device that contains a processor and memory.

In one implementation, the communication device 102 is incorporated into the physical structure of the regenerative fuel cell 100 and is a processor coupled to memory. This implementation can provide for a display and an input device to be connected externally to the regenerative fuel cell 100 allowing the display and input device to communicate with the processor and memory for monitoring and controlling. The display can be any device that allows for data to be displayed to a user. For example, an LCD display, monitor, TV, or other similar device. The input device can be any device that allows for entry or selection of data such as a mouse, pointing device, input device, keypad, keyboard, light pen, remote control, shortcut buttons, or any other related entry device.

In another implementation, the communication device 102 is incorporated into the physical structure of the regenerative fuel cell 100 and comprises a processor coupled to memory, a display, and an input device. The display and input device can be the same as discussed above except that they would be internal rather than external to the regenerative fuel cell 100.

In another implementation, the communication device 102 is not physically incorporated into the structure of the regenerative fuel cell 100, but is directly connected to the regenerative fuel cell 100 to provide monitoring and controlling. For example, the direct connection can be cable, wire, electrical wiring connection, or any other related connection mechanism. The communication device in this implementation can be a computer.

In an exemplary implementation of a communication device, the communication device 102 is configured as a computer as illustrated in Figures 1 and 6. The communication device 102 can be a computer with the hardware architecture including a display 600, input device 404 (keyboard 602, pointing device 604), CPU (Central Processing Unit) 606, memory 608, I/O controller 610, disk controller 612, hard drive 614, floppy drive 616, optical drive 618, modem 620, and network card 622. Each of the devices intercommunicate over bus 624 either directly or over their respective interfaces or controllers. The computer is not limited to these generally common devices as the computer can and does include any other computer related devices.

The communication device 102 can include a software system in any of the above implementations. The software system can include any of the following an operating system (OS), communication software, graphical user interface (GUI), and software applications. The operating system manages all the programs in the communication device 102 referred to as software applications.

The operating system can be any standard operating system for use on a communication device. For example, the operating system can be Microsoft Windows™, Microsoft Windows 95™, Microsoft Windows 98™, Microsoft Windows 2000™, Microsoft Windows NT™, Microsoft Windows CE™, any Microsoft Windows based operating system, the Palm™ OS, Mac OS™, IBM OS/2™, Unix, Linux, PLC based, proprietary based, or any other similar based operating system. The operating system will preferably allow a communication device 102 to communicate with external devices and run related applications. The communication software allows the communication device 102 to send data to and receive data from external devices over the communication interface 712.

The graphical user interface (GUI) can be any program that allows information to be displayed to a user. For example, a proprietary software program or an Internet web browser (web browser) can be used. The Internet web browser can be any software that will communicate with an Internet server over the communication interface 102 such as Netscape Navigator™, Netscape Communicator™, Microsoft Internet Explorer™, HotJava™, Mosaic™, Opera™, or similar related web browser software.

The communication device 102 is connected to the regenerative fuel cell 100 so that the communication device 102 can be the master control to operate each component independently or dependently. The communication device 102 can be connected to associated sensors, relays, electronic components, or electrical devices of the regenerative fuel cell 100 for monitoring and controlling all aspects of operation. In addition, the communication device 102 can provide for tracking operational and statistical information regarding the regenerative fuel cell 100. For example, the communication device 102 can store information including power usage, fuel consumption, fuel storage unit 702 information, second reactant storage unit 706

information, reaction product storage unit 704 information, fuel regenerator 708 information, and fuel regeneration information.

The communication device 102 can provide for updating and storing information regarding the operation and performance of the regenerative fuel cell 100 to other communication devices, which will be discussed further below. The communication device 102 can operate independently of the regenerative fuel cell 100 in communicating with powered devices and other communication devices as shown in Figures 2 and 4, which will be discussed further below. The implementations of the present invention is not dependent on any particular device and can be implemented in various configurations and architectures.

A second embodiment of the power management system in accordance with the subject invention is illustrated in Figure 2 in which, compared to Figure 1, like elements are referenced with like identifying numerals. The power management system of Figure 2, includes, as before, a regenerative fuel cell 100, a communication device 102, and further includes an interface 202 and at least one powered device 200.

The interface 202 is connected to the regenerative fuel cell 100. The interface 202 comprises at least one of a power interface 710 or a communication interface 712 as illustrated in Figure 7. The power interface 710 and the communication interface 712 can be the same interface or each can be a different interface.

The power interface 710 allows for the power management system to be easily interconnected with the existing electrical power wiring of a facility, structure, building, or vehicle to perform power management. For example, the existing electrical power wiring can become part of the power interface 710. The power interface 710 is configured to deliver electricity generated by the regenerative fuel cell 100. The power interface 710 can also receive electricity from at least one energy source as shown in Figure 3, which will be discussed further below.

The power interface 710 provides for any conversion or conditioning that needs to take place in supplying or receiving electricity. In one implementation, , the power interface 710 can convert the DC generated by the regenerative fuel cell 100 and convert it to AC for supplying to at least one powered device 200. In another

implementation, the power interface 710 can receive AC and convert it to DC for use by the regenerative fuel cell 100. The power interface 710 can also supply and receive DC without the need for conversion. Generally, it is preferable for any power conversion and conditioning hardware portion of the power interface 710 to be located, on, or within the regenerative fuel cell.

The communication interface 712 can be any interface that allows the sending and receiving of data. In one implementation, the communication interface 712 is a wireless based system such as cellular based, digital cellular, GSM (Global System for Mobile communication), PCS (Personal Communications Services), PDC (Personal Digital Cellular), radio communications, or satellite communications system. The wireless based systems as discussed above can utilize either a Wireless Application Protocol (WAP) or Bluetooth Wireless Technology Standard for sending and receiving data over the communication interface 712. WAP is a specification for a set of communication protocols to standardize the way that wireless communication devices can be used for Internet access, including email, the World Wide Web (WWW), Usenet, and Internet Relay Chat (IRC). The Bluetooth Wireless Technology Standard is a computing and telecommunications industry specification that describes how mobile phones, computers, and PDAs (personal digital assistants) can easily interconnect with each other and with home and business phones and computers using a short-range wireless connection.

In one implementation, the communication interface 712 is a land-line based system such as a local area network (LAN), wide area network (WAN), ISDN (Integrated Services Digital Network), DSL (Digital Subscriber Line), xDSL (ADSL, HDSL, RADSL), Internet Cable, cable modem, PPP (Point-to-Point Protocol) connections, fiber-optic cabling, or electrical wiring. The electrical wiring, for example, can be the existing power wiring in a building, structure, facility, or vehicle.

Internet access or Internet communication is considered to be inherent in any implementation of the communication interface 712. Selection and incorporation of such a communication interface will be apparent to those of skill in the art.

In another implementation, the communication interface 712 is the Internet. The Internet is a global network of computers referred to as servers which are accessible by communication devices, often referred to as "user nodes" or "client computers." These communication devices typically access the Internet through Internet Service Providers (ISPs), On-line Service Providers (OSPs), or direct Internet connections. Each computer on the Internet, referred to as a host, has at least one address that uniquely identifies it from all other computers on the Internet often referred to as an IP (Internet Protocol) address.

The at least one powered device 200 can be any device that is electric consuming as illustrated in Figures 2 and 12. The at least one powered device 200 comprises at least one selected from the group of an energy usage system, security system, environmental system, commercial devices 1200, consumer devices 1202, industrial devices 1204, manufacturing devices, vehicles, automobiles 1208, trucks 1206, trailer, recreational vehicle, motorcycle, smart appliances, household appliances, engines, computers, telecommunication equipment, cellular base stations, distributed terminals, sensors, electrical devices located onboard a vehicle, or any electric powered device.

The at least one powered device 200 can also include a communication capability for sending data to and receiving data from the communication device 102 over the communication interface. The at least one powered device 200 can provide for monitoring and controlling other powered devices.

In one implementation, the communication device 102 can monitor and control the regenerative fuel cell 100 to send and receive electricity along with allowing communication of data between the regenerative fuel cell 100 and an external device over a communication interface 712. The external device can be an at least one powered device or at least one other communication device.

The communication device 102 can perform energy management within a building or structure. For example, the communication device 102 can monitor for energy usage of powered devices 200, a regenerative fuel cell 100, or electricity used within a building including all independent loads. The fuel contained within the

regenerative fuel cell 100 is regenerated using at least one energy source 300. The implementations of the present invention is not dependent on any particular device and can be implemented in various configurations and architectures.

A third embodiment of the power management system in accordance with the subject invention is illustrated in Figure 3 in which, compared to Figure 2, like elements are referenced with like identifying numerals. The power management system of Figure 3, includes, as before, a regenerative fuel cell 100, a communication device 102, an interface 202, at least one powered device 200, and further includes at least one energy source 300.

The at least one energy source 300 can be any source used for supplying electricity to the regenerative fuel cell 100, communication device 102, and at least one powered device 200 at any time before, during, or after operations. Alternatively, the at least one energy source can receive power generated from the regenerative fuel cell 100 in the form of AC or DC. The at least one energy source 300 can deliver power as AC (alternating current) or DC (direct current) depending on the type of source.

In one implementation, the at least one energy source 300 can be selected from the following group a reciprocating engine, combustion engine, regional electric grid, rotating engine, solar energy collector, battery, generator, turbine, water wheel, flywheel, capacitor, wind energy collector, or any similar related device or combination as discussed above.

In one implementation example, the at least one energy source 300 supplies power to all components of the regenerative fuel cell 100 including the fuel cell 700, fuel regenerator 708, fuel storage unit 702, reaction product storage unit 704, any electric consuming devices on the fuel cell, pumps, blowers, and the optional second reactant storage unit 706. The at least one energy source 300 supplies power as either AC or DC through the power interface 710 to the regenerative fuel cell 100. The power interface 710 will make any necessary power conversions for supplying DC to the perspective components such as AC into DC.

In another implementation example, the at least one energy source 300 supplies power to the communication device 102. The at least one energy source 300 can be

configured to directly supply power to the communication device 102. Alternatively, the at least one energy source 300 can supply power indirectly to the communication device 102 through delivering the power to the regenerative fuel cell 100. In either case, the at least one energy source 300 will deliver the power through the power interface and the proper power conversion will take place.

In another implementation example, the at least one energy source 300 can be configured to supply primary power to at least one powered device 200 at any time. The at least one energy source 300 can supply power to the at least one powered device 200 through a direct connection. The direct connection can be any power interface that allows for the sending of electricity. Alternatively, the at least one energy source 300 can supply power to the at least one powered device 200 over the power interface 710. In this configuration, the at least one energy source 300 can supply power over the power interface independent of the regenerative fuel cell 100 or under the control of the communication device 102. The power interface 710 can also reduce harmonic distortion of power delivered to the at least one powered device 200 (power conditioning). The at least one energy source 300 can be configured to power to the at least one powered device 200 during the period immediately following loss of power and until the regenerative fuel cell 100 can provide power. The at least one energy source 300 can be configured to provide extra power for at least one powered device 200 when the regenerative fuel cell 100 is simultaneously powering at least one powered device 200.

In another implementation example, the at least one energy source 300 can receive power from the regenerative fuel cell 100. The regenerative fuel cell 100 can send generated electricity over the power interface 710 directly to the regional electric grid. This allows a business using the power management system to sell back electricity to the Utility company resulting in cost savings for both. In this implementation, the power interface 710 can match the phase and power factor of the generated electricity to those required for selling electricity to the Utility company. In addition, the power interface 710 can condition the generated electricity to meet the requirements needed for sending electricity to the regional grid.

A fourth embodiment of the power management system in accordance with the subject invention is illustrated in Figure 4 in which, compared to Figure 2, like elements are referenced with like identifying numerals. The power management system of Figure 4, includes, as before, a regenerative fuel cell 100, a communication device 102, an interface 202, at least one powered device 200, and further includes a user interface 400.

The user interface 400 comprises a second communication device 402 and an input device 404. The second communication device 402 can be any communication device that allows for data to be sent and received over the communication interface 712. In an implementation, the second communication device 402 can be at least one selected from the group comprising a computer, networked computers, server system, mainframe, laptop, handheld computer, PDA (personal digital assistant), mobile phone, facsimile machine, telephone, video phone, pager, or any other device containing a processor and memory.

The second communication device 402 is in communication with the input device 404 for inputting data by a user 406. The input device 404 can be any device or combination of device that allows for a user 406 to input data to the second communication device 402. The input device 404 is at least one selected from the group comprising manual entry system, voice communication system, thought process system, or any other related system. In one implementation, the input device 404 is a manual manipulation system that can be accomplished by the user 406 using a touch screen, keyboard, keypad, pointing device, mouse, light pen, remote control, or shortcut buttons. In another implementation, the input device 404 is a voice communication system that includes a voice recognition system incorporated into the second communication device, whereby the user speaks into a microphone and the second communication device translates the voice data so that the second communication device will automatically select the user's selection or the input of data. In another implementation, the input device 404 is a thought process system incorporated into the second communication device to allow hands free entry. Neural attachments could be secured to the user's head so that brain waves or brain electrical signals could be

translated by the second communication device providing for the second communication device to automatically select the user's selection or input of data. Selection and incorporation of such a second communication device and user interface will be apparent to those of skill in the art.

Figure 6 is a detailed block diagram of an exemplary implementation of a second communication device 402. The second communication device 402 is a computer with the hardware architecture including display 600, input device 404 (keyboard 602, pointing device 604), CPU (Central Processing Unit) 606, memory 608, I/O controller 610, disk controller 612, hard drive 614, floppy drive 616, optical drive 618, modem 620, and network card 622. Each of the devices intercommunicate over bus 624 either directly or over their respective interfaces or controllers. The computer is not limited to these generally common devices as the computer can and does include any other computer related devices.

The second communication device 402 can include a software system in any of the above implementations. The software system can comprise of any of the following an operating system (OS), communication software, graphical user interface (GUI), and software applications. The operating system manages all the programs in the second communication device 402 referred to as software applications. The operating system can be any standard operating system for use on the second communication device 402. For example, the operating system can be Microsoft Windows™, Microsoft Windows 95™, Microsoft Windows 98™, Microsoft Windows 2000™, Microsoft Windows NT™, Microsoft Windows CE™, any Microsoft Windows based operating system, the Palm™ OS, Mac OS™, IBM OS/2™, Unix, Linux, PLC based, proprietary based, or any other similar based operating system.

The operating system will allow the second communication device 402 to communicate with a communication device 102 and run related applications. The communication software allows the second communication device 402 to send and receive information to external devices over the communication interface 712. The graphical user interface (GUI) can be any program that allows information to be displayed on the second communication device 402. For example, a proprietary

software program or an Internet web browser (web browser) can be used. The Internet web browser can be any software that will communicate with an Internet server over the communication interface such as Netscape Navigator™, Netscape Communicator™, Microsoft Internet Explorer™, HotJava™, Mosaic™, Opera™, or similar related web browser software.

A web browser is an application program that provides a mechanism to view and interact with information on the WWW, which is generally in the form of web pages. A web browser is a type of "HTTP client", which allows a user to send HTTP (Hypertext Transfer Protocol) requests to an HTTP server (web server) and receive back an HTTP response that is viewable on the web browser in the form of a web page or other similar related format.

In an implementation example as illustrated in Figures 4, 6, and 11, the second communication device 402 is configured as a computer providing for connection with the communication interface 712 which could, for example, be the Internet. The computer can connect to the Internet by a modem 620, network card 622, or any other communication interface that will allow interface between the computer and the Internet. The network card 622 allows the computer to be connected to a LAN (local area network) and/or WAN (wide area network) which communicate with a HUB and router in making a connection to the Internet. The implementations of the present invention is not dependent on any particular device and can be implemented in various configurations and architectures.

A fifth embodiment of the power management system in accordance with the subject invention is illustrated in Figure 5 in which, compared to Figures 1-4, like elements are referenced with like identifying numerals. The power management system of Figure 5, includes a regenerative fuel cell 100, a communication device 102, an interface 202, at least one powered device 200, at least one energy source 300, and a user interface 400. This embodiment incorporates and includes all implementations as discussed above in the previous embodiments.

In this embodiment, the entire power management system provides for monitoring and controlling of the regenerative fuel cell 100 and at least one powered

device 200. The power management system may also monitor and control at least one energy source 300. The monitoring and controlling includes communicating with the regenerative fuel cell 100, at least one powered device 200, at least one energy source 300, and a user interface 400. Further, the system can deliver power either from the regenerative fuel cell 100 or from the at least one energy source 300 responsive to data received by the communication device 102 from the at least one powered device 200 or from the user interface 400. The at least one energy source 300 provides power to the power management system and all components when needed and available. A user 406 can utilize the input device 404 for inputting data to the second communication device 402 and then transfer that data or request to the communication device 102 over the communication interface 712. The communication device 102 can process that data and communicate with external devices or adjust the operation of the regenerative fuel cell 100.

In one implementation, the communication interface 712 can comprise different physical components and different communication methods for sending and receiving data between the communication device 102, the at least one powered device 200, and the user interface 400. In one example implementation, the communication interface 712 between the communication device 102 and the at least one powered device is electrical power wiring within a building. In addition, the communication interface 712 between the communication device 102 and the user interface 400 is the Internet.

The implementations of the present invention is not dependent on any particular device and can be implemented in various configurations and architectures.

Figure 8 is a flow diagram of an exemplary method of the present invention for remotely monitoring and controlling the regenerative fuel cell 100. In step 800, user 406 inputs data over the input device 404 as illustrated in Figure 4. The data input by the user 406 can be any information that will be used for monitoring and controlling the power management system. For example, the data can comprise control parameters for the regenerative fuel cell 100, control parameters for at least one powered device 200, control parameters for the at least one energy source 300, power usage parameters, or any other information for controlling the power management system.

In step 802, the data is received at the second communication device 402. In one implementation, the data can appear on the display of the second communication device 402. The data can be stored on the second communication device 402 for later retrieval. In step 804, the second communication device 402 establishes a connection over the communication interface 712 to the first communication device 102 as illustrated in Figure 4.

In step 806, the second communication device 402 transmits the data to the first communication device 102 over the communication interface 712. In one implementation, the second communication device 402 will use an Internet web browser to transmit the data over the communication interface 712, which will be the Internet, to the first communication device 102.

In step 808, the first communication device 102 receives the data. In step 810, the first communication device 102 updates and stores the data. In one implementation, the first communication device 102 can update and store control parameters for the regenerative fuel cell 100, the at least one energy source 300, and/or the at least one powered device 200. The first communication device 102 can then use the stored control parameters to adjust power usage of the regenerative fuel cell 100 and/or at least one powered device 200. The first communication device 102 can also communicate the updated control parameters to the at least one powered device 200 and at least one source 300, which will be discussed further below.

In step 812, the first communication device 102 can use the data to configure the regenerative fuel cell 100 to deliver or receive power responsive to the data. In one implementation, the data can be control parameters instructing the regenerative fuel cell 100 to deliver power to at least one powered device 200 or at least one energy source 300 based on a certain criteria. For example, the criteria could be a cost range for the price of electricity. The cost range could be set so when the cost of electricity reaches a certain cost, the first communication device 102 will configure the regenerative fuel cell 100 to deliver power to at least one powered device 200 and/or at least one energy source 300 at a lower cost, rather than continuing to use electricity supplied by the Utility company 1100 at a higher cost. As illustrated in Figure 12, the first

communication device 102 can provide for the ability to communicate over the communication interface 712 with the Utility company 1100 to request the price of electricity or to retrieve power usage information. The first communication device 102 can then analyze that information and based on that information activate the regenerative fuel cell 100 to deliver power to the at least one powered device 200.

In another implementation, the data could be control parameters instructing the regenerative fuel cell 100 to deliver power to at least one energy source 300 based on a criteria. The at least one energy source 300 could be the regional electric grid, otherwise known as the "Utility company 1100." For example, the criteria could be a power usage range where the first communication device 102 detects that the Utility company 1100 has requested power delivery. The first communication device 102 could then supply excess generated power from the regenerative fuel cell 100 to the Utility company 1100 for a profit. Alternatively, the Utility company 1100 could communicate over the communication interface 712 with the first communication device 102 to request power delivery to the grid. The first communication device 102 could activate the regenerative fuel cell 100 and deliver power to the Utility company 1100 based on their request.

Figure 9 is a flow diagram of an exemplary method of the present invention for a communication device 102 to monitor and control at least one powered device 200.

In step 900, the communication device 102 is initialized for sending and receiving data over the communication interface 712. In step 902, the communication device 102 establishes a connection to at least one powered device 200 over the communication interface 712 as illustrated in Figures 2 and 11. In one implementation, the communication device 102 will use an Internet web browser to transmit the data over the communication interface 712, which will be the Internet, to the at least one powered device 200. In another implementation, the communication device 102 will send and receive data through the electrical power wiring of a building. In another implementation, the communication device 102 will send and receive data via electromagnetic waves using a wireless system.

In step 904, the communication device 102 will gather data from at least one powered device 200. The data can be any information pertaining to the operation and control of the at least one powered device 200. For example, the data can comprise power usage information, , environmental information, operating parameters, control parameters, or any other operational information.

In one implementation, the communication device 102 will send a request to the at least one powered device 200 over the communication interface 712 to receive data. Alternatively, the communication device 102 will send data to be stored on the at least one powered device 200 over the communication interface 712. In this implementation, the powered device 200 will have processing capability for sending, receiving, and storing data over the communication interface 712.

In another implementation,. the at least one powered device 200 will have no processing capability. A smart adapter can be plugged into an electrical outlet and then the at least one powered device 200 plugged into the smart adapter. The smart adapter will have processing capability for sending, receiving, and storing data over the communication interface 712. The smart adapter can receive and store updated control parameters from the communication device 102 to adjust and monitor the power consumption of the at least one powered device 200. Therefore, the smart adapter becomes the processor for the at least one powered device 200.

In another implementation, the at least one powered device 200 will be a switch and have no processing capability. The switch can turn power on and off to other powered devices. The position of the switch (open or closed) will be controlled by the communication device 102 via the power interface 710 or communication interface 712.

In one implementation, the at least one powered device 200 can request and gather information from other powered devices. For example, the communication device 102 can request information from a environmental control system located in a building. Once the environmental control system receives that request, the environmental control system can then request information from other powered devices 200 within the system such as an air conditioner, heater, ventilation system, and other similar powered devices. This implementation will be discussed in further detail below.

In step 906, the at least one powered device 200 will process the data request from the communication device 102 by transmitting the data from at least one powered device 200 to the communication device 102 over a communication interface 712. In step 908, the communication device 102 in control of the regenerative fuel cell 100 will receive the data and store the data on the communication device 102. The communication device 102 can be integrated with the regenerative fuel cell 100 by physical incorporation or a direct connection.

In step 910, the data can optionally be transmitted through at least one other communication device to a user. In one implementation, the other communication devices can be the same as the second communication device 402 as illustrated in Figures 4 and 11. All implementations and embodiments for the second communication device 402 can be considered the same as for the at least one other communication device. The at least one other communication device can display and store the data for later retrieval. A user 406 can utilize software on the other communication device to process the data for cost analysis and savings or operational improvement.

In step 912, the communication device 102 can compare the data received in step 906 from the at least one powered device 200 against preset control parameters supplied by a user. The preset control parameters could be supplied to the communication device 102 in the method set forth above in the Figure 8 flow diagram process. The communication device 102 can use any form of comparison method that will result in an analysis of the data. The preset control parameters can help the communication device 102 determine if the at least one powered device 200 is operating within the proper operating range. For example, if the preset control parameters were the temperature for at least one powered device 200, then the communication device 102 can use the data sent from the powered device 200 to determine if the powered device is operating at the proper temperature.

In one implementation example, the at least one powered device 200 could be a commercial meat freezer with processing capability that the communication device 102 can monitor and control. The communication device 102 could request the freezer's power usage, temperature, light usage, and other related operating

information. The communication device 102 could also periodically request the current price of electricity from the Utility company 1100 under a time-of-day pricing agreement wherein the price of electricity varies each hour. In response to that information and the preset control parameters received from the user 406, the communication device 102 could then adjust all of those parameters each independently by sending instructions to the freezer to make changes in the operation of the freezer.

For example, the user 406 may input the following preset control parameters for the freezer temperature: maintain at 0°F unless the cost of electricity exceeds \$0.15/kWh, in which case allow the temperature to rise to 5°F, except on Mondays from 5AM to noon, when the temperature should be held at minus 5°F regardless of cost, because new meat shipments arrive every Monday at 5AM. The lights in the freezer should be kept on from midnight to 4PM Monday through Friday and turned off at other times. The communication device 102 would then control the operation of the freezer accordingly.

In one implementation example, the communication device 102 can act as the main control for a security system. Sensors, locking mechanisms, and surveillance equipment could be connected to the communication device 102 for direct monitoring and control. Alternatively, the communication device 102 could monitor and control an existing main control for a security system.

In step 914, the communication device 102 will have completed the comparison performed in step 912. If the communication device 102 determines that it is needed, the communication device 102 can activate the regenerative fuel cell 100 to supply power to at least one powered device 200. For example, if power to the at least one powered device 200 stops, the communication device 102 can activate the regenerative fuel cell 100 to supply power to the powered device 200. The communication device 102 can also supply power to at least one powered device 200 when the communication device determines that the electricity being delivered by from the regional grid system is not reliable or is too expensive.

For example, in the commercial meat freezer implementation above, the user 406 may preset an additional parameter telling the communication device 102 to

activate the regenerative fuel cell to supply power to the freezer when the cost of electricity exceeds $0.20/kWh from the Utility company 1100 and to receive power for fuel regeneration when the cost of electricity is less than $0.10/kWh.

In one implementation, the method further comprises the steps of receiving the updated control parameters by at least one powered device 200, sending the updated control parameters from the powered device 200 to other powered devices, and adjusting operation to perform within the updated control parameter. In an implementation example, the at least one powered device 200 could be the main control for a security system within a building. The main control can receive updated control parameters from the communication device 102 over the communication interface 712. The main control can then send the updated control parameters to other sub-components of the security system for adjusting operation to perform within the updated control parameters. For example, the main control can receive a command to turn the lights off at a certain time and to activate the motion detectors, the main control can then turn the lights off at that time and activate the motion detectors or instruct controllers to turn the lights off and activate the motion detectors at a certain time.

In another implementation, a user 406 could have the ability to remotely monitor and control at least one powered device 200 by communicating over the communication interface 712 with the communication device 102. The user 406 could input parameters for controlling all aspects of at least one powered device 200 including power usage, communication, or other related items.

Figure 10 is a flow diagram of an exemplary method of the present invention for monitoring and controlling a regenerative fuel cell 100 and at least one powered device 200 through the use of a communication device 102, the communication device monitors for power delivery requests. The implementations and implementation examples along with the detailed discuss above for the first embodiment is hereby incorporated into the description of this method.

In step 1000, the communication device 102 detects a power need or receives power delivery requests as illustrated in Figure 13. The power need or power delivery requests can be received over the communication interface 712. The communication

device 102 can detect a power need from the control parameter comparison or by sensors or components that will notify the communication device 102 of power need or loss. A power delivery request will notify the communication device 102 to activate the regenerative fuel cell 100 to deliver power to the requesting device. The power delivery request can come from any device connected to the power management system. For example, at least one powered device 200 or at least one energy source 300 can make power delivery requests. Alternatively, a user 406 could make a power delivery request directly to the communication device 102 as illustrated in Figure 4. The user 406 could instruct the communication device 102 to initiate the regenerative fuel cell 100 to deliver power. The user 406 could be the Utility company 1100 making a direct request for power delivery to at least one powered device 200 or to the regional utility grid.

In step 1002, the communication device 102 activates the regenerative fuel cell 100 by commands. In step 1004, the fuel is combined with a second reactant for electrochemically reacting. In step 1006, electricity is generated and a reaction product is produced from the reaction. In step 1008, the generated electricity is delivered.

In one implementation, the regenerative fuel cell 100 provides reliable electricity to auxiliary electric devices such as a radio, TV, mobile phone, facsimile machine, air conditioner, microwave, or other related electrical devices onboard a vehicle such as a truck, recreational vehicle, boat, or car. In this configuration, the regenerative fuel cell 100 could be connected to the vehicle's alternator or to a solar panel on the roof or deck of the vehicle to accept DC current. The regenerative fuel cell 100 would use the supplied DC current to power the processes for electricity generation and fuel regeneration. Alternatively, the regenerative fuel cell 100 could be configured to completely power the vehicle without the need for DC current from a vehicle's alternator. The regenerative fuel cell 100 could propel the vehicle with zero –emissions and when parked be refueled or plugged in to at least one energy source 300 to regenerate the fuel.

In one implementation example, the regenerative fuel cell 100 could be used to power auxiliary devices onboard a sleeper cab on a long-haul Class 8 truck when the truck is parked for loading, unloading, and driver rest periods. The fuel could be

regenerated while the truck is moving using DC electricity generated by the truck's alternator. In another implementation example, the regenerative fuel cell 100 could be used to power auxiliary devices onboard a sailboat or yacht when the boat is anchored away from port at night. The fuel could be regenerated during the day using a solar panel on the deck of the boat or by DC electricity generated by an alternator when the yacht's main engines are running.

In another implementation, the power management system may incorporate an electricity meter, thereby making it a useful replacement for present electricity meters. The electric meter can be in communication with the communication device 102 included with the regenerative fuel cell 100 and at least one powered device 200. The electric meter in this configuration can be used to determine an electric bill along with other useful information.

In another implementation, the power management system may incorporate a system for recovering waste heat from the regenerative fuel cell 100 and using the waste heat to heat air or water.

Figure 14A is a block diagram of an embodiment of a power management system according to the invention. In this embodiment, communication device 1406 manages providing power to one or more loads 1408(1), 1408(2), . . ., 1408(n) responsive to data received from a source. The communication device 1406 may operatively engage, responsive to the data, one or the other of the energy source 1402 and the regenerative fuel cell 1404 to provide power to the one or more loads 1408(1), 1408(2), . . ., 1408(n). The communication device 1406 may operatively disengage, responsive to the data, one or the other of the energy source 1402 and the regenerative fuel cell 1404 from providing power to the one or more loads 1408(1), 1408(2), . . ., 1408(n). The communication device 1406 may also adjust, responsive to the data, the power requirements of the one or more loads 1408(1), 1408(2), . . ., 1408(n).

In one implementation, the energy source 1402 and a regenerative fuel cell 1404 may alternate between providing power to one or more loads 1408(1), 1408(2), . . . , 1408(n). Upon the occurrence of a first specified condition, the communication device 1406 may operatively engage a selected one of the regenerative fuel cell 1404 and the

energy source 1402 to provide power to the one or more loads 1408(1), 1408(2), . . ., 1408(n). Upon the occurrence of a second specified condition, which may be different from the first, the communication device 1406 may operatively disengage the selected one of the energy source 1402 and the regenerative fuel cell 1404 from providing power to the one or more loads, and operatively engage the other of the energy source 1402 and regenerative fuel cell 1404 to provide power to the one or more loads 1408(1), 1408(2), . . ., 1408(n).

The energy source 1402 may be any source of electrical power, including without limitation, a source of solar or wind power, an internal combustion engine or other device which converts fossil fuel into electrical energy, a public utility, regional electric grid, a diesel generator, a nickel cadmium battery, a reciprocating engine, rotating engine, solar energy collector, battery, generator, turbine, water wheel, flywheel, capacitor, or wind energy collector. For purposes of this disclosure, the phrase "energy source" includes within its scope a power source.

The regenerative fuel cell 1404 may include a fuel storage unit, a regeneration unit, and a device which undergoes an electrochemical reaction which releases energy, in the process consuming fuel which has been supplied to the device source. The fuel storage unit stores additional fuel which may be provided to the device after the latter has been depleted. The regeneration unit may process back into fuel one or more reaction products which may be produced through the electrochemical reaction which occurs in the device. Additional detail regarding the structure and operation of the regenerative fuel cell 1404 will be provided further on in this disclosure.

Communication device 1406 may be configured to manage, responsive to data received from a source, providing power to the one or more loads 1408(1), 1408(2), 1408(n) from one or the other of the energy source 1402 and the regenerative fuel cell 1404. In one implementation, communication device 1406, upon the occurrence of a first specified condition, operatively engages regenerative fuel cell 1404 to provide power to the one or more loads 1408(1), 1408(2), 1408(n), and operatively disengages energy source 1402 from providing power to the one or more loads 1408(1), 1408(2), . . . , 1408(n). In this implementation, upon the occurrence of a second specified

condition, communication device 1406 may further be configured to operatively re-engage energy source 1402 to provide power to the one or more loads 1408(1), 1408(2), 1408(n), and operatively disengage regenerative fuel cell 1404 from providing power to the one or more loads 1408(1), 1408(2), 1408(n). For purposes of this disclosure, the phrase "communication device" includes within its scope a controller which may be implemented in hardware, software or a combination of hardware and software.

The one or more loads 1408(1), 1408(2), 1408(n) may each be any system or device which consumes electrical power including without limitation an air conditioning or heating system for a building, vehicle, or home; a consumer device, such as a refrigerator; or computing equipment, such as a computer, server, workstation, docking station, printer, etc.

In addition, each of the one or more loads 1408(1), 1408(2), . . . , 1408(n) may each be an energy usage system, security system, environmental system, commercial device, consumer device, industrial device, manufacturing device, vehicle, automobile, truck, trailer, recreational vehicle, motorcycle, smart appliance, household appliance, engine, computer, telecommunication equipment, cellular base station, distributed terminal, sensor, electrical device located onboard a vehicle, or any electric powered device.

Each of the links 1410a, 1410b, 1410c, 1410d, 1410e may be any communication medium or media capable of transmitting electrical power, including one or more wireless links such as Bluetooth, or one or more wireline links, such as a link comprised of one or more computer networks, such the Internet, etc. In one embodiment, one or more of the links 1410a, 1410b, 1410c, 1410d, 1410e is also capable of transmitting data, unidirectionally or bidirectionally.

For example, one or more of the links may each be a wireless link selected from the group comprising a cellular based link, digital cellular link, GSM (Global System for Mobile communication) link, PCS (personal communications services) link, PDC (personal digital cellular) link, radio communications link, or satellite communications

link. One or more of the wireless links may each employ a WAP (wireless application protocol) or a Bluetooth wireless technology standard for sending and receiving data.

One or more of the links may each be a wireline link selected from the group comprising a local area network link, wide area network link, ISDN (integrated services digital network) link, DSL (digital subscriber line) link, xDSL (ADSL, HDSL, RADSL) link, Internet Cable link, cable modem link, PPP (point-to-point protocol) link, modem, telephone link, or electrical wiring.

Each of the first and second specified conditions may each be any condition, including without limitation conditions based on time of day, the price of power from energy source 1402, the price of power from regenerative fuel cell 1404, the relative price between power from energy source 1402 and regenerative fuel cell 1404, scheduled load usage periods, etc.

In one implementation, link 1410a is operative to communicate data to communication device 1406 regarding time of day pricing of the power from energy source 1402. Communication device 1406 may be configured, responsive to this information, to operatively engage, during peak usage periods when power from energy source 1402 is expensive, regenerative fuel cell 1404 to provide power to the one or more loads 1408(1), 1408(1), 1408(n) and/or operatively disengage energy source 1402 from providing power to the one or more loads. Communication device 1406 may also be configured, during off peak usage periods, when power from energy source 1402 is inexpensive, to operatively engage energy source 1402 to provide power to the one or more loads 1408(1), 1408(2), . . . , 1408(n), and/or operatively disengage the regenerative fuel cell 1404 from providing power to the one or more loads 1408(1), 1408(2), . . . , 1408(n). During these off-peak usage periods, the regeneration unit within regenerative fuel cell 1404 may also be powered by energy source 1402 to process one or more reaction products back into fuel for use by the regenerative fuel cell 1404 during the peak usage periods.

An advantage of the foregoing is that cost savings may be realized in that power from energy source 1402 may be utilized (to produce fuel for regenerative fuel cell 1404) during off-peak usage periods when this power is less expensive, and then power

from the regenerative fuel cell 1404 may be used to power the one or more loads during the peak usage periods when power from energy source 1402 is more expensive.

Figure 14B is a block diagram of another embodiment of a power management system according to the invention in which, compared to Figure 14A, like elements are referenced with like identifying numerals. In this embodiment, energy source 1402 provides power to the regeneration unit (not shown) within regenerative fuel cell 1404. In one implementation, the energy source 1402 provides power to the regeneration unit within regenerative fuel cell 1404 during those time periods in which regenerative fuel cell 1404 is operatively disengaged from providing power to the one or more loads 1408(1), 1408(2), . . . , 1408(n). In another implementation, the energy source 1402 provides power to the regeneration unit within regenerative fuel cell 1404 during those time periods in which energy source 1402 is operatively engaged to provide power to the one or more loads 1408(1), 1408(2), . . . , 1408(n). In one implementation example, the energy source 1402 provides power to the regeneration unit within regenerative fuel cell 1404 during off-peak usage periods when energy source 1402 is operatively engaged to provide power to the one or more loads 1408(1), 1408(2), . . . , 1408(n).

Figure 14C is a block diagram of another embodiment of a power management system according to the invention in which, compared to Figures 14A-14B, like elements are referenced with like identifying numerals. In this embodiment, a memory 1414 is provided which is accessible by communication device 1406 through link 1416. Data representative of one or more parameters or rules may be stored within the memory 1414. The communication device 1406 may be configured, responsive to these one or more parameters or rules, to operatively engage one or the other of energy source 1402 and regenerative fuel cell 1404 to provide power to the one or more loads 1408(1), 1408(2), . . ., 1408(n). Alternatively, or in addition, the communication device 1406 may also be configured, responsive to these one or more parameters or rules, to operatively disengage one or the other of energy source 1402 and regenerative fuel cell 1404 from providing power to the one or more loads 1408(1), 1408(2), . . . , 1408(n).

The communication device 1406 may be configured to retrieve the one or more rules or parameters from energy source 1402 and store the same in memory 1414. In this case, the link 1410a should be capable of carrying digital data in addition to power from energy source 1402. Alternatively, the communication device 1406 may retrieve this information from an external source (not shown) and store it in memory 1414. In one implementation, this information is available from a selected site on the Internet. The communication device 1406 in this implementation may be configured to log onto the Internet, retrieve the information from the selected site, and store the information in memory 1414. Again, the link for accessing the selected site may be a wireless, wireline, or other link, which is capable of carrying digital data.

The communication device 1406 may also be configured to retrieve the one or more rules or parameters from one or more of the loads 1408(1), 1408(2), . . . , 1408(n). In this case, one or more of the links 1410c, 1410d, 1410e, should be capable of carrying digital data in addition to power from one or the other of energy source 1402 and regenerative fuel cell 1404.

In addition, the communication device 1406 may also be configured to adjust the power requirements of one or more of the loads 1408(1), 1408(2), . . ., 1408(n) through the links 1410c, 1410d, and 1410e.

In one implementation, one or more of the loads 1408(1), 1408(2), . . . , 1408(n) are intelligent devices, and the one or more rules or parameters are retrieved from one or more of these intelligent devices and stored in the memory 1414.

The one or more rules or parameters may originate from multiple sources. For example, time of day pricing information regarding power from energy source 1402 may be obtained from energy source 1402, and information regarding scheduled periods of usage for a load may be obtained from that load. This information may all be stored in the memory 1414 and used to determine when and how power is delivered to the load. In one configuration, the communication device 1406 is configured to operatively engage regenerative fuel cell 1404 to provide power to the load when (1) the time of day pricing information indicates an off-peak usage period when power from energy source 1402 is expensive; and (2) the scheduling information from the load indicates

a usage period for the load. In this configuration, the communication device 1406 may also be configured to operatively engage energy source 1402 to provide power to the load when (1) the time of day pricing information indicates a peak usage period when power from energy source 1402 is less expensive; and (2) the scheduling information from the load indicates a usage period for the load. In this configuration, both the energy source 1402 and the regenerative fuel cell 1404 are operatively disengaged from providing power to the load when the scheduling information indicates a non-usage period for the load.

Figure 14D is a block diagram of another embodiment of a power management system according to the invention in which, compared to Figures 14A-14C, like elements are referenced with like identifying numerals. In this embodiment, user input device 1418 is also provided for inputting one or more of the rules or parameters. These one or more rules or parameters may be received by communication device 1406 and stored in memory 1414 for use, either alone or in combination with one or more rules or parameters from other sources, in managing providing power from one or the other of energy source 1402 and regenerative fuel cell 1404 in the manner previously described.

In one example, one or more rules may be input to communication device 1406 from a personal computer. The one or more rules may, for example, specify that a certain consumer device such as a refrigerator is to run at 34°F unless the price of power from energy source 1402 (which is assumed to provide primary power to the refrigerator) exceeds 18¢/kilowatt hour, in which case, the refrigerator is to run at 36°F except for Mondays, when a family member typically visits, in which case, the refrigerator is to run at 32°F. The one or more rules may also specify, for example, that the regenerative fuel cell 1404 should be switched to provide power to the refrigerator if the price of primary power from energy source 1402 exceeds 22¢/kilowatt hour. Responsive to these one or more rules, communication device 1406 may switch between providing power to the refrigerator from the energy source 1402 and the regenerative fuel cell 1404, and may also adjust the temperature at which the refrigerator is operating (which determines the power requirements for the refrigerator).

This example is provided solely to illustrate an application of a power management system according to the invention, and should not be construed as limiting.

The input device may be any device capable of allowing a user to input data including without limitation a keyboard, touch-activated screen, keypad, pointing device, input device, mouse, light pen, remote control device, device employing shortcut buttons or any other related entry device.

The input device may further be a voice-activated computer, RF transmitter, mobile phone or handset, personal digital assistant, a processor coupled to memory, mainframe, server system, computer, mainframe, laptop, handheld computer, facsimile machine, telephone, video phone, or similar device.

The input device may further include a graphical user interface which, in one implementation, is an Internet web browser. The device may further include a voice recognition system for receiving voice information from a user speaking into a microphone, and translating the voice information into digital information.

In one embodiment, the communication device 1406 is configured to track power usage information for one or the other or both of the energy source 1402 or the regenerative fuel cell 1404.

An implementation of communication device 1406 is illustrated in Figure 15A in which, compared to Figures 14A-14D, like elements are referenced with like identifying numerals. In this implementation, logic 1422 is coupled to memory 1414 over link 1416. The logic 1422 may be hardware, software, or a combination of hardware and software. In one example, the logic 1422 is a microprocessor configured to execute a series of instructions stored in a memory, which may be memory 1414 or another memory. In another, the logic 1422 comprises one or more asynchronous integrated circuits (ASIC) embodying a finite state machine. In another, the logic 1422 is a digital signal processor (DSP) configured to execute instructions stored in a memory, which may be memory 1414 or some other memory. The memory 1414 may be any device capable of storing digital data, including, without limitation, RAM, ROM, EPROM, EEPROM, flash memory, PROM, disk, floppy disk, hard disk, CD-ROM, DVD, etc.

In this implementation, the logic 1422 may be configured to retrieve one or more rules or parameters from energy source 1402 over link 1410a(2), which is capable of carrying digital data, and storing the same in memory 1414. Alternatively, or in addition, the logic 1422 may be configured to retrieve one or more parameters from load 1408(i) over link 1410z(1), which is capable of carrying digital data, and storing the same in memory 1414. Alternatively, or in addition, the logic 1422 may be configured to retrieve one or more rules or parameters from external source 1428 over link 1426, which is capable of carrying digital data, and storing the same in memory 1414. External source 1428 may be but is not limited to a site on the Internet. Alternatively, or in addition, logic 1422 may be configured to control, over link 1410z(1), the power requirements of load 1408(i).

Logic 1422 is configured, responsive to one or more of these rules or parameters, to operatively engage or disengage one or the other of energy source 1402 or regenerative fuel cell 1404 in relation to load 1408(i) or adjust the power requirements of load 1408(i). If energy source 1402 is operatively engaged in relation to load 1408(i), power from energy source 1402 is provided over link 1410a(1) to logic 1422, and from logic 1422 to load 1408(i) over link 1410z(2). If regenerative fuel cell 1404 is operatively engaged in relation to load 1408(i), power from the regenerative fuel cell 1404, which may be DC power, is provided to logic 1422, and then to DC-AC converter 1424, which converts the DC power from regenerative fuel cell 1404 into AC power. The AC power from the DC-AC converter 1424 is then provided to load 1408(i) over link 1410z(3).

A second implementation of communication device 1406 is illustrated in Figure 15A in which, compared to Figure 15B, like elements are referenced with like identifying numerals. In this implementation, communication device 1406, in lieu of or in addition to link 1426 to external source 1428, includes user input device 1418, which is configured to allow a user to input one or more rules or parameters, and provide the same to logic 1422 over link 1420. Once received by logic 1422, the one or more rules or parameters may be provided to memory 1414 over link 1416. These one or more parameters may then be used, singly or in combination with one or more rules or

parameters from other sources, for operatively engaging or disengaging one or the other of energy source 1402 and regenerative fuel cell 1404 in relation to load 1408(i), and/or adjusting the power requirements of load 1408(i).

Implementations of communication device 1406 are also possible which are combinations or variants of the foregoing. For example, the regenerative fuel cell 1404 may output AC power, in which case the DC-AC converter 1424 may be omitted and the AC power from regenerative fuel cell 1404 provided directly to load 1408(i) when the same is operatively engaged. Or the load 1408(i) may only require DC power, and again, the DC power from regenerative fuel cell 1404 provided directly to load 1408(i) when the same is operatively engaged. Furthermore, implementations are possible where the logic 1422 receives one or more of the rules or parameters from one, more than one, or any combination of, the sources which have been indicated: energy source 1402, load 1408(i), external source 1428, or input device 1418. In addition, implementations are possible where the logic 1422 may receive one or more of the rules or parameters from regenerative fuel cell 1404.

Moreover, implementations of communication device 1406 are possible wherein power to the one or more loads 1408(1), 1408(2), . . . , 1408(n) is controlled separately. In such an implementation, rules or procedures may be maintained by communication 1406 for each of the loads separately, and separate ones of the energy source 1402 and regenerative fuel cell 1404 may be provided for each of the loads. The rules or procedures may be used to separately drive the process of operatively engaging or disengaging one or more of the energy source 1402 or regenerative fuel 1404 in relation to the loads, and/or adjusting the power requirements of the loads.

A block diagram of one embodiment of regenerative fuel cell 1404 is illustrated in Figure 16. As illustrated, the fuel cell comprises a device 1620, an optional reaction product storage unit 1622, a regeneration unit 1624, a fuel storage unit 1626, and an optional second reactant storage unit 1628. The device 1620 in turn comprises one or more cells each having a cell body defining a cell cavity, with an anode and cathode situated in each cell cavity. The cells may be coupled in parallel or series. In one implementation, they are coupled in series to form a cell stack.

The anodes within the cell cavities are composed of the fuel stored in fuel storage unit 1626. Within the cell cavities of device 1620, an electrochemical reaction takes place whereby the anode releases electrons, and forms one or more reaction products. Through this process, the anodes are gradually consumed. The released electrons flow through a load to the cathode, where they react with the second reactant from optional second reactant storage unit 1628 or from some other source. The flow of electrons through the load gives rise to a voltage for the cells. When the cells are combined in series, the sum of the voltages for the cells forms the output of the device 1620.

The one or more reaction products may then be provided to optional reaction product storage unit 1622 or to some other destination. The one or more reaction products, from unit 1622 or some other source, may then be provided to regeneration unit 1624, which regenerates fuel and the second reactant from the one or more reaction products. The fuel may then be provided to fuel storage unit 1626, and the second reactant may then be provided to optional second reactant storage unit 1628 or to some other destination.

In one embodiment, the fuel cell is a zinc/air fuel cell where the anodes are formed of zinc (Zn) particles, and the fuel stored in fuel storage unit 1626 consists of liquid born zinc particles immersed in a potassium hydroxide (KOH) electrolyte. The second reactant in this embodiment is oxygen from the ambient air. Since the second reactant is from the ambient air, the optional second reactant storage unit 1628 may be excluded in this embodiment. A recirculating flow of the fuel borne zinc particles may be maintained through the cell cavities in order to deliver KOH to the particulate anodes and to replenish these anodes. As the potassium hydroxide contacts the zinc anodes, the following reaction may take place at the anodes:

$$Zn + 4OH^- \rightarrow Zn(OH)_4^{2-} + 2e^- \qquad (1)$$

The two released electrons flow through a load to the cathode where the following reaction may take place:

$$\frac{1}{2}O_2 + 2e^- + H_2O \rightarrow 2OH^- \qquad (2)$$

The reaction product is the zincate ion, $Zn(OH)_4^{2-}$, which is soluble in the reaction solution KOH. The overall reaction which occurs in the cell cavities is the combination of the two reactions (1) and (2). This combined reaction can be expressed as follows:

$$Zn + 2OH^- + \frac{1}{2}O_2 + H_2O \rightarrow Zn(OH)_4^{2-} \quad (3)$$

Alternatively, the zincate ion, $Zn(OH)_4^{2-}$, may be allowed to precipitate to zinc oxide, ZnO, a second reaction product, in accordance with the following reaction:

$$Zn(OH)_4^{2-} \rightarrow ZnO + H_2O + 2OH^- \quad (4)$$

In this case, the overall reaction which occurs in the cell cavities is the combination of the three reactions (1), (2), and (4). This overall reaction can be expressed as follows:

$$Zn + \frac{1}{2}O_2 \rightarrow ZnO \quad (5)$$

Under real world conditions, the reactions (4) or (5) yield a voltage potential of about 1.4V. For additional information on this embodiment of a zinc/air battery, the reader is referred to U.S. Patent Nos. 5,952,117; 6,153,329; and 6,162,555, which are hereby incorporated by reference herein as though set forth in full.

The reaction product $Zn(OH)_4^{2-}$, and also possibly ZnO, may be provided to reaction product storage unit 1622. Regeneration unit 1624 may then reprocess these reaction products to yield oxygen, which is released to the ambient air, and zinc particles, which provided to fuel storage unit 1626. The regeneration of the zincate ion, $Zn(OH)_4^{2-}$, into zinc, may occur according to the following overall reaction:

$$Zn(OH)_4^{2-} \rightarrow Zn + 2OH^- + H_2O + \frac{1}{2}O_2 \quad (6)$$

The regeneration of zinc oxide, ZnO, into zinc may occur according to the following overall reaction:

$$ZnO \rightarrow Zn + \frac{1}{2}O_2 \quad (7)$$

In a second embodiment of a fuel cell, the fuel used in the electrochemical reaction which occurs within the cells is hydrogen, the second reactant is oxygen, and

the reaction product is water. In this embodiment, the hydrogen fuel is maintained in the fuel storage unit 1626, but the second reactant storage unit 1628 may be omitted and the oxygen used in the electrochemical reaction within the cells may be taken from the ambient air. In addition, the reaction product storage unit 1622 may be omitted and the water resulting from discharge of the unit simply discarded. Later, the regeneration unit 1624 may regenerate water from another source, such as tap water, into hydrogen and oxygen. The hydrogen may then be stored in fuel storage unit 1622, and the oxygen simply released into the ambient air.

An advantage of fuel cells relative to traditional energy or power sources such as lead acid batteries is that they can provide longer term backup power more efficiently and compactly. This advantage stems from the ability to continuously refuel the fuel cells using fuel stored with the fuel cell and regenerated from reaction products by the regeneration unit. In the case of the zinc/air fuel cell, for example, the duration of time over which energy can be provided is limited only by the amount of fuel which is initially provided in the fuel storage unit, and which can be regenerated from the reaction products which are produced.

Figure 17 is a flowchart of one embodiment of a method of operation according to the invention. As illustrated, in step 1702, data is received from a source which may be an energy source, a regenerative fuel cell, one or more loads, a user input device, or an external source such as an Internet site. The data may be representative of one or more rules or procedures. Step 1704 follows step 1702. In step 1702, power from one or the other of an energy source and a regenerative fuel cell to one or more loads is managed responsive to the data. This step may comprises operatively engaging, responsive to the data, one or the other of the energy source and the regenerative fuel cell to provide power to the one or more loads. It may comprise operatively disengaging, responsive to the data, one or the other of the energy source and the regenerative fuel cell from providing power to the one or more loads. It may also comprises adjusting, responsive to the data, the power requirements of the one or more loads. It may also comprises any combination of the foregoing.

In one implementation, the regenerative fuel cell is operatively engaged to provide power to the one or more loads during peak usage periods, when power from the energy source is expensive. During off-peak usage periods, when power from the energy source is less expensive, the energy source is operatively engaged to provide power to the one or more loads. During these off-peak usage periods, the energy source may also be used to drive a regeneration unit within the regenerative fuel cell.

In this implementation, the data used to drive the process may be time of day pricing information received from the energy source, the regenerative fuel cell, a user input device, or an external source such as an Internet site.

While embodiments, implementations, and implementation examples have been shown and described, it should be apparent that there are many more embodiments, implementations, and implementation examples that are within the scope of the subject invention. Accordingly, the invention is not to be restricted, except in light of the appended claims and their equivalents.

WE CLAIM:

1. A system for power management, comprising:

(a) a regenerative fuel cell; and

(b) a controller configured to (1) receive data from a source; and (2) manage, responsive to the data, providing power from one or the other of an energy source and the regenerative fuel cell to one or more loads.

2. The system of claim 1 wherein the controller is configured to operatively engage, responsive to the data, one or the other of the energy source and the regenerative fuel cell to provide power to the one or more loads.

3. The system of claim 1 wherein the controller is configured to operatively disengage, responsive to the data, one or the other of the energy source and the regenerative fuel cell from providing power to the one or more loads.

4. The system of claim 3 wherein the controller is configured to adjust, responsive to the data, the power requirements of the one or more loads.

5. The system of claim 1, wherein the regenerative fuel cell comprises a fuel storage unit for storing fuel, a device for electrochemically reacting the fuel with a second reactant to release electricity, a reaction product storage unit for storing reaction product resulting from the reaction, and a fuel regeneration unit for electrochemically recovering the fuel from the reaction product.

6. The system of claim 5, wherein the regenerative fuel cell further comprises a second reactant storage unit.

7. The system of claim 5, wherein the fuel is hydrogen.

8. The system of claim 5, wherein the fuel is zinc.

9. The system of claim 5, wherein the second reactant is oxygen.

10. The system of claim 1, wherein the energy source is configured to supply primary power to the one or more loads.

11. The system of claim 10, wherein the regenerative fuel cell is configured to supply backup power to the one or more loads.

12. The system of claim 1, wherein the regenerative fuel cell is configured to supply primary power to the one or more loads.

13. The system of claim 12, wherein the energy source is configured to supply backup power to the one or more loads.

14. The system of claim 1 wherein the source of data is the power source.

15. The system of claim 1 wherein the source of data is the one or more loads.

16. The system of claim 1 wherein the source of data is a user input device.

17. The system of claim 1 wherein the source of data is an external device.

18. The system of claim 1 wherein the controller further comprises a memory for storing the data.

19. The system of claim 1 wherein the data represents one or more rules or procedures.

20. The system of claim 1 wherein the controller is configured to operatively engage the regenerative fuel cell to provide power to the one or more loads during peaks usage periods, and operatively engage the energy source to provide power to the one or more loads during off-peak usage periods.

21. The system of claim 20 wherein the controller is configured to operatively disengage the energy source from providing power to the one or more loads during off-peak usage periods, and to operatively disengage the regenerative fuel cell from providing power to the one or more loads during peak usage periods.

22. A method of providing power to one or more loads, comprising:

(a) receiving data from a source;

(b) managing, responsive to the data, providing power from one or the other of an energy source and a regenerative fuel cell to one or more loads.

23. The method of claim 22 further comprising operatively engaging, responsive to the data, one or the other of an energy source and a regenerative fuel cell to provide power to the one or more loads.

24. The method of claim 22 further comprising operatively disengaging, responsive to the data, one or the other of an energy source and a regenerative fuel cell from providing power to the one or more loads.

25. The method of claim 22 wherein the data represents one or more rules or parameters.

26. The method of claim 22 further comprising receiving the data from the energy source.

27. The method of claim 22 further comprising receiving the data from one or more of the loads.

28. The method of claim 22 further comprising receiving the data from a user input device.

29. The method of claim 22 further comprising receiving the data from an external source.

30. The method of claim 29 wherein the external source is an Internet site.

31. The method of claim 22 further comprising storing the data in a memory.

32. The method of claim 22 further comprising operatively engaging the energy source to provide power to the one or more loads during off-peak usage periods, and operatively engaging the regenerative fuel to provide power to the one or more loads during peak usage periods.

33. The method of claim 32 further comprising operatively disengaging the energy source from providing power to the one or more loads during peak usage periods, and operatively disengaging the regenerative fuel cell from providing power to the one or more loads during off-peak usage periods.

34. The method of claim 32 further comprising powering a regeneration unit of the regenerative fuel cell during the off-peak usage periods.

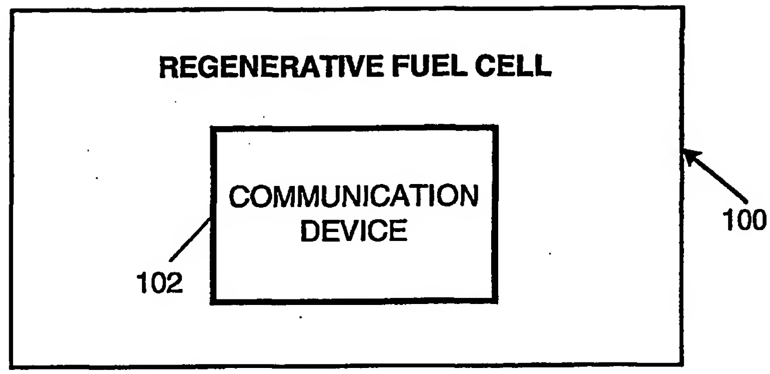

FIGURE 1

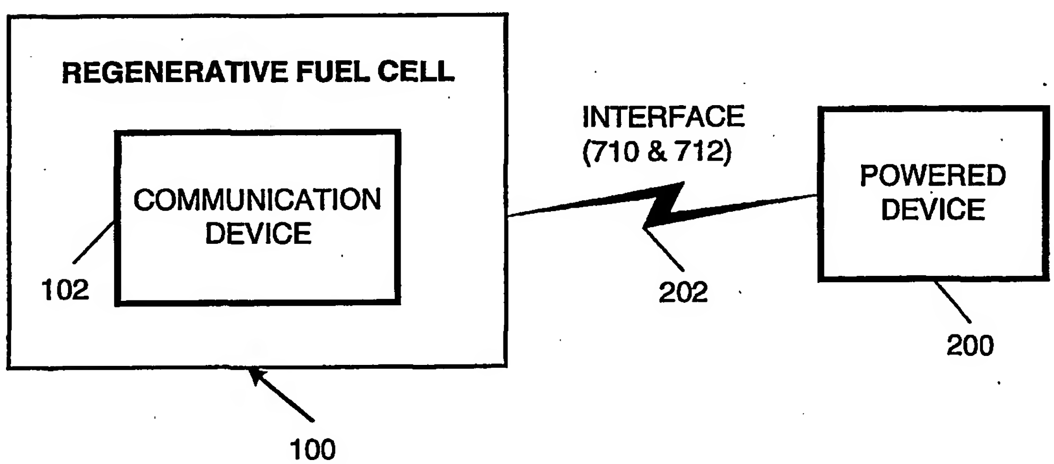

FIGURE 2

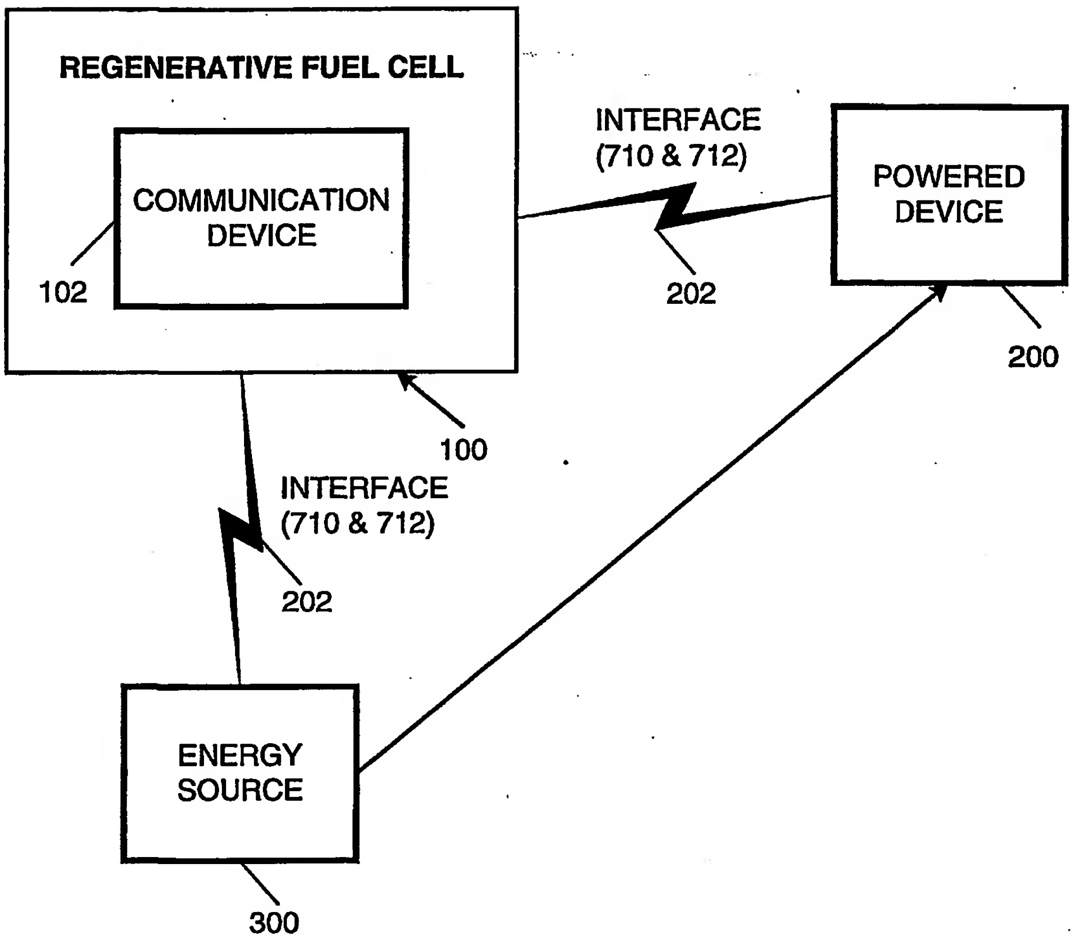
REGENERATIVE FUEL CELL
COMMUNICATION DEVICE
102
INTERFACE
(710 & 712)
POWERED DEVICE
202
200
100
INTERFACE
(710 & 712)
202
ENERGY SOURCE
300

FIGURE 3

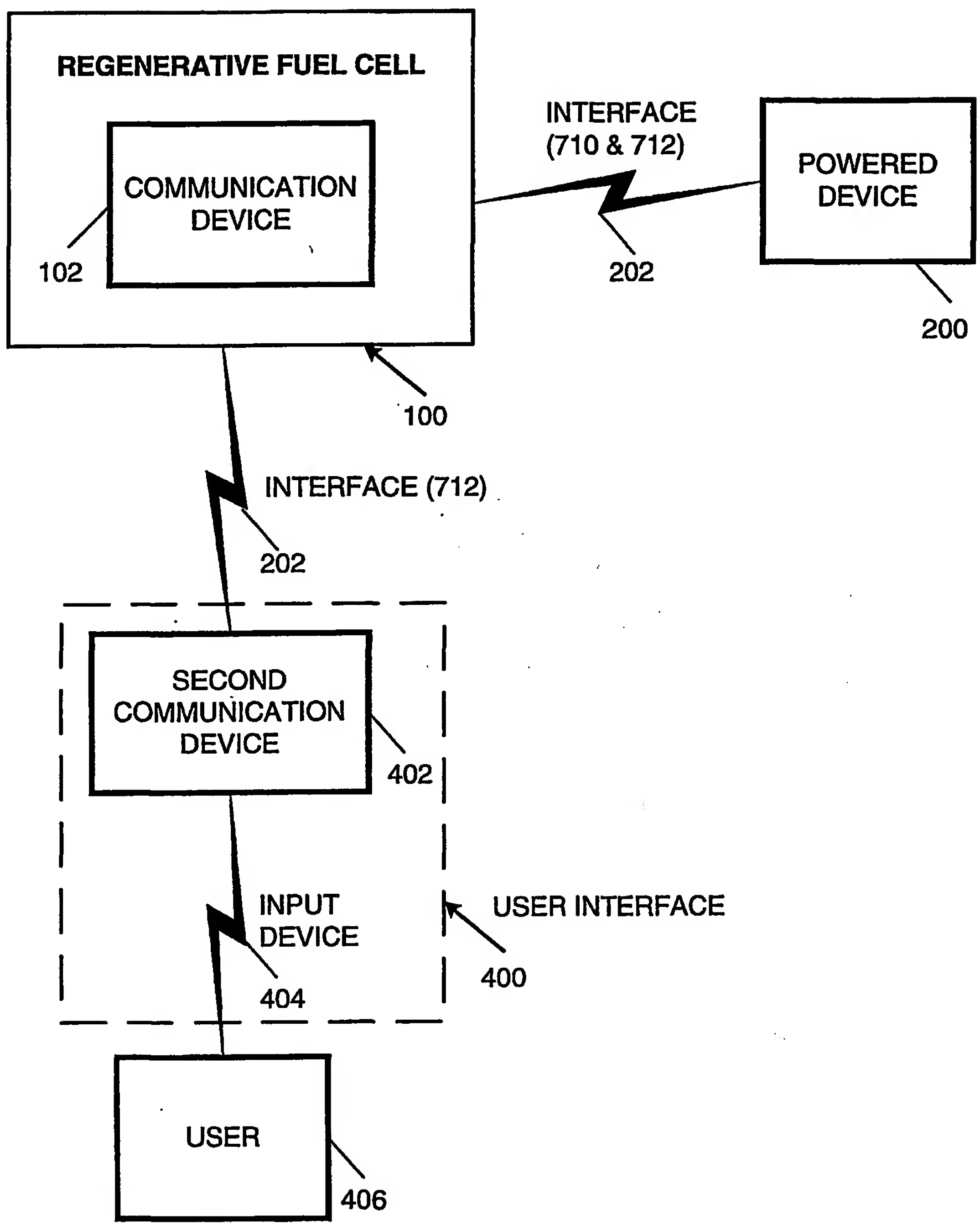
REGENERATIVE FUEL CELL
COMMUNICATION DEVICE
102
INTERFACE (710 & 712)
POWERED DEVICE
202
200
100
INTERFACE (712)
202
SECOND COMMUNICATION DEVICE
402
INPUT DEVICE
404
USER INTERFACE
400
USER
406

FIGURE 4

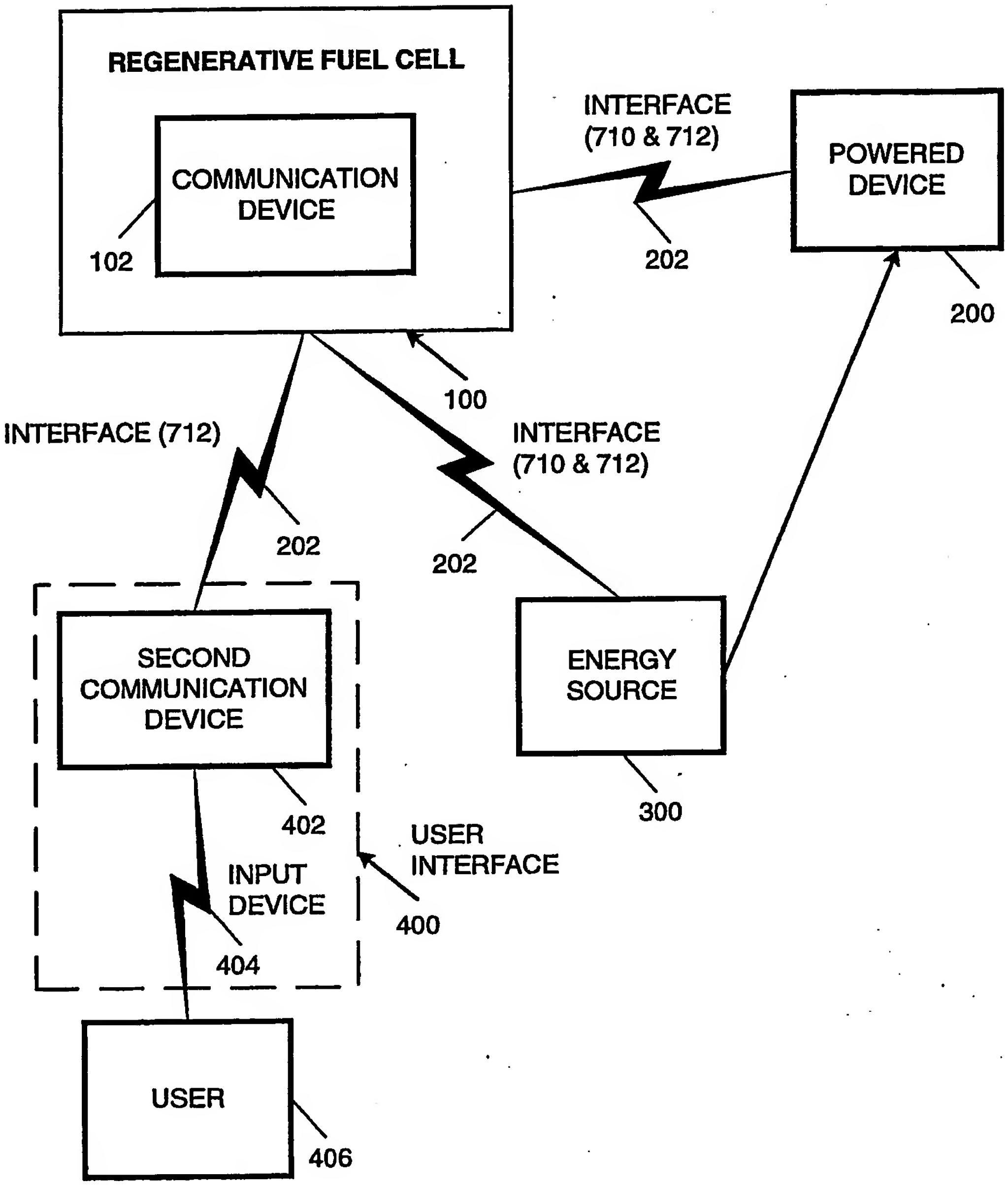
REGENERATIVE FUEL CELL
COMMUNICATION DEVICE
102
INTERFACE
(710 & 712)
POWERED DEVICE
202
200
100
INTERFACE (712)
INTERFACE
(710 & 712)
202
202
SECOND COMMUNICATION DEVICE
ENERGY SOURCE
402
300
USER
INTERFACE
INPUT
DEVICE
400
404
USER
406

FIGURE 5

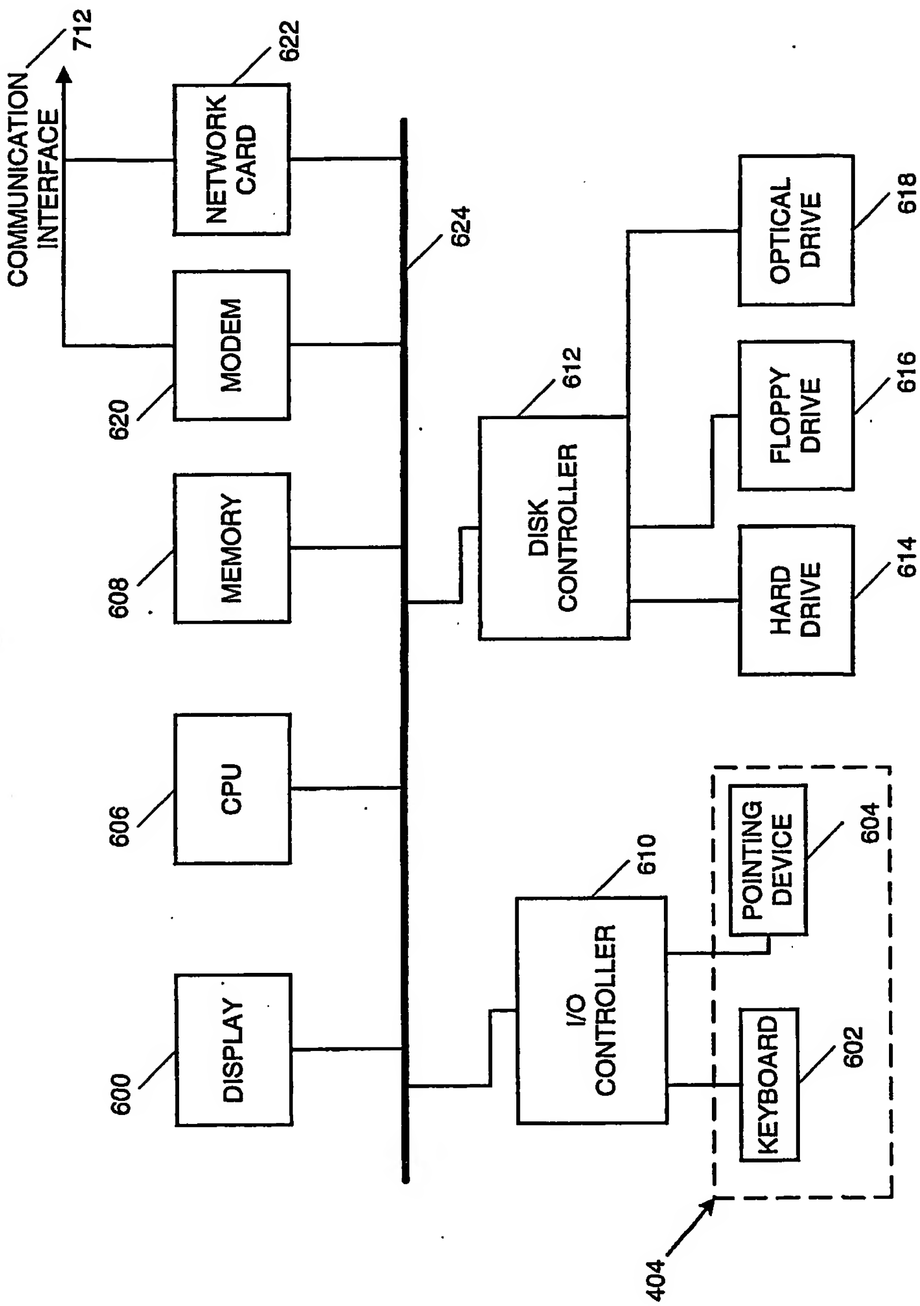
COMMUNICATION INTERFACE
712
NETWORK CARD
622
MODEM
620
MEMORY
608
CPU
606
DISPLAY
600
624
DISK CONTROLLER
612
OPTICAL DRIVE
618
FLOPPY DRIVE
616
HARD DRIVE
614
I/O CONTROLLER
610
POINTING DEVICE
604
KEYBOARD
602
404

FIGURE 6

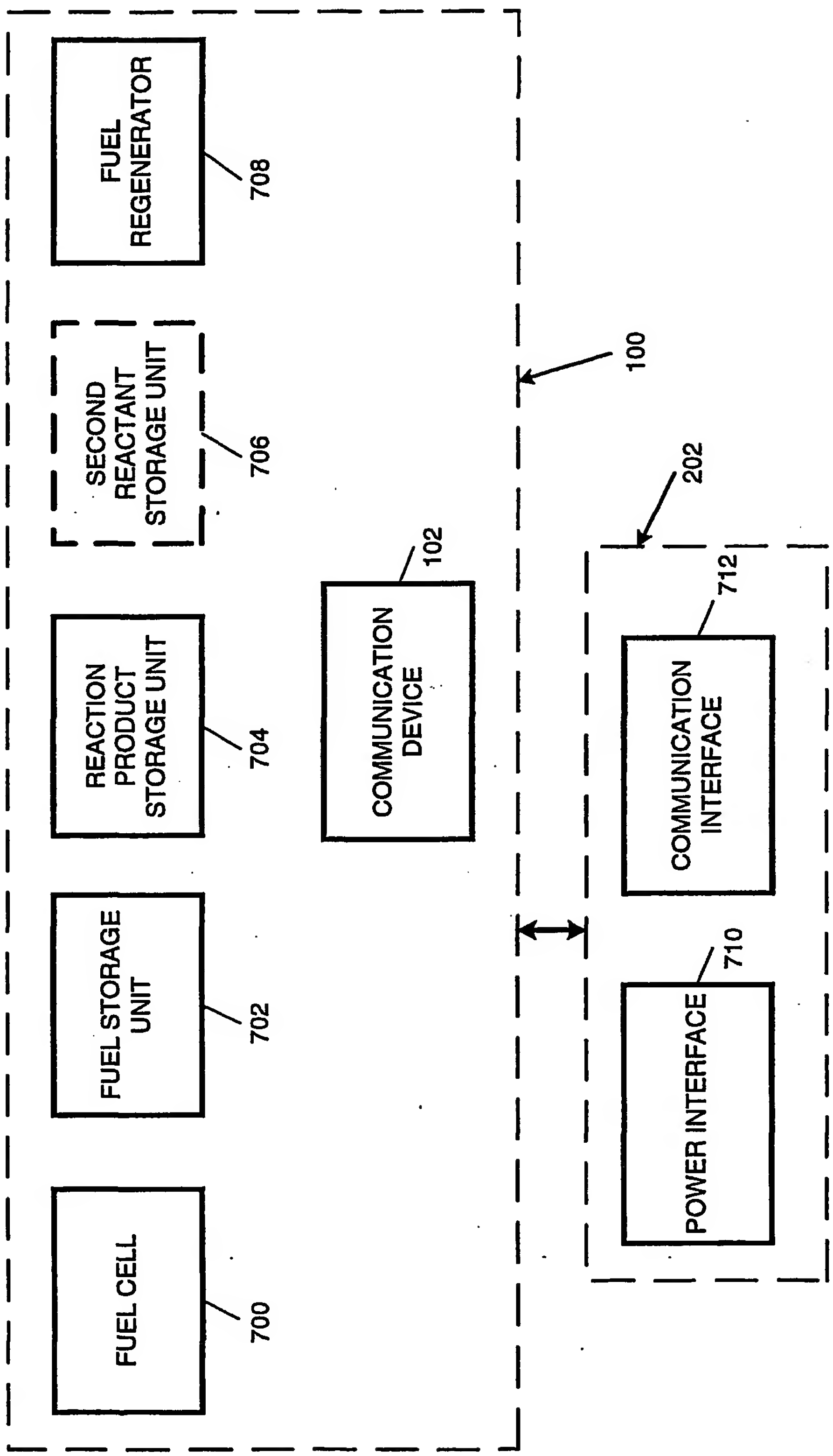
FUEL REGENERATOR
708
SECOND REACTANT STORAGE UNIT
706
REACTION PRODUCT STORAGE UNIT
704
FUEL STORAGE UNIT
702
FUEL CELL
700
COMMUNICATION DEVICE
102
100
202
COMMUNICATION INTERFACE
712
POWER INTERFACE
710

FIGURE 7

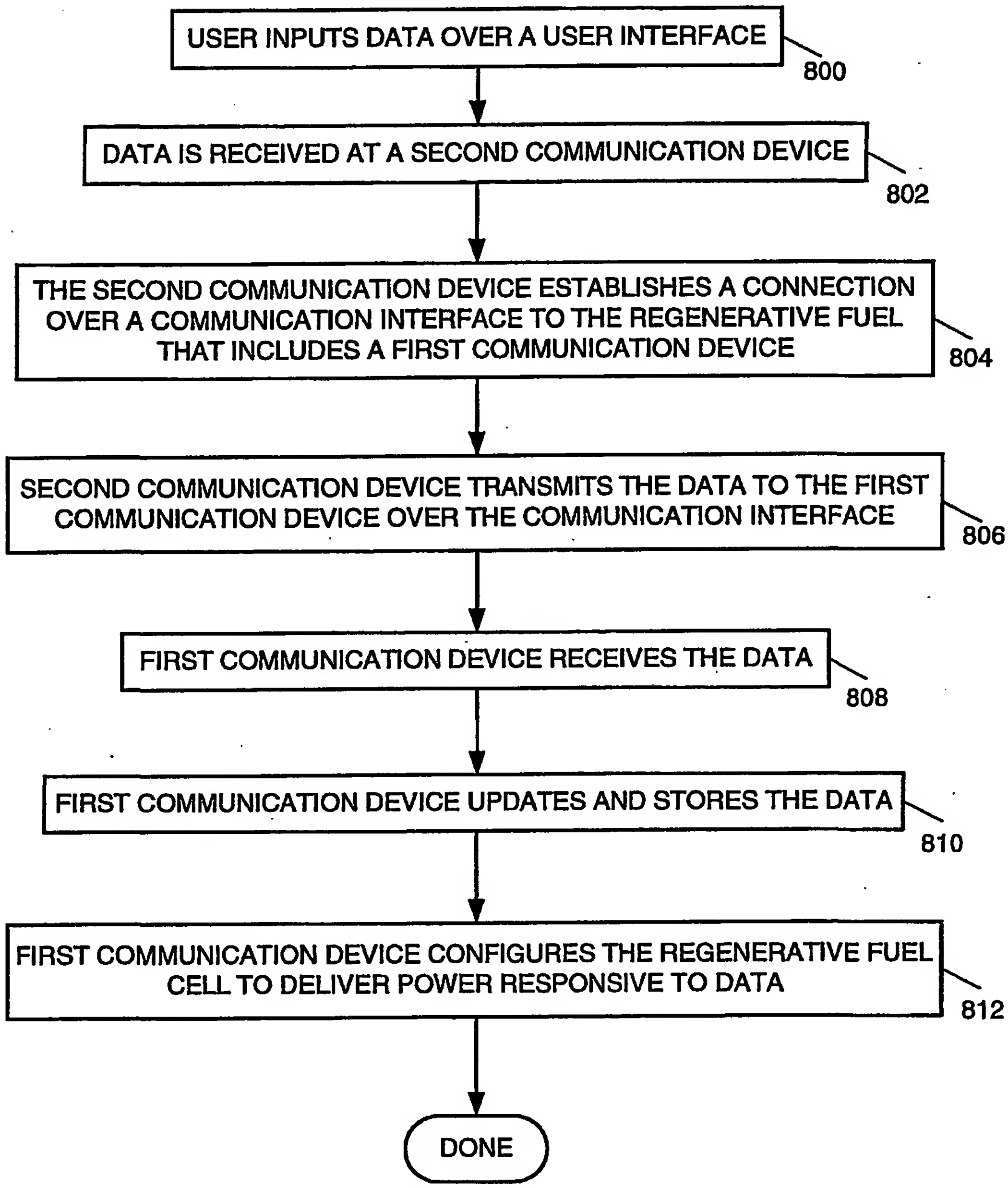
USER INPUTS DATA OVER A USER INTERFACE
800
DATA IS RECEIVED AT A SECOND COMMUNICATION DEVICE
802
THE SECOND COMMUNICATION DEVICE ESTABLISHES A CONNECTION OVER A COMMUNICATION INTERFACE TO THE REGENERATIVE FUEL THAT INCLUDES A FIRST COMMUNICATION DEVICE
804
SECOND COMMUNICATION DEVICE TRANSMITS THE DATA TO THE FIRST COMMUNICATION DEVICE OVER THE COMMUNICATION INTERFACE
806
FIRST COMMUNICATION DEVICE RECEIVES THE DATA
808
FIRST COMMUNICATION DEVICE UPDATES AND STORES THE DATA
810
FIRST COMMUNICATION DEVICE CONFIGURES THE REGENERATIVE FUEL CELL TO DELIVER POWER RESPONSIVE TO DATA
812
DONE

FIGURE 8

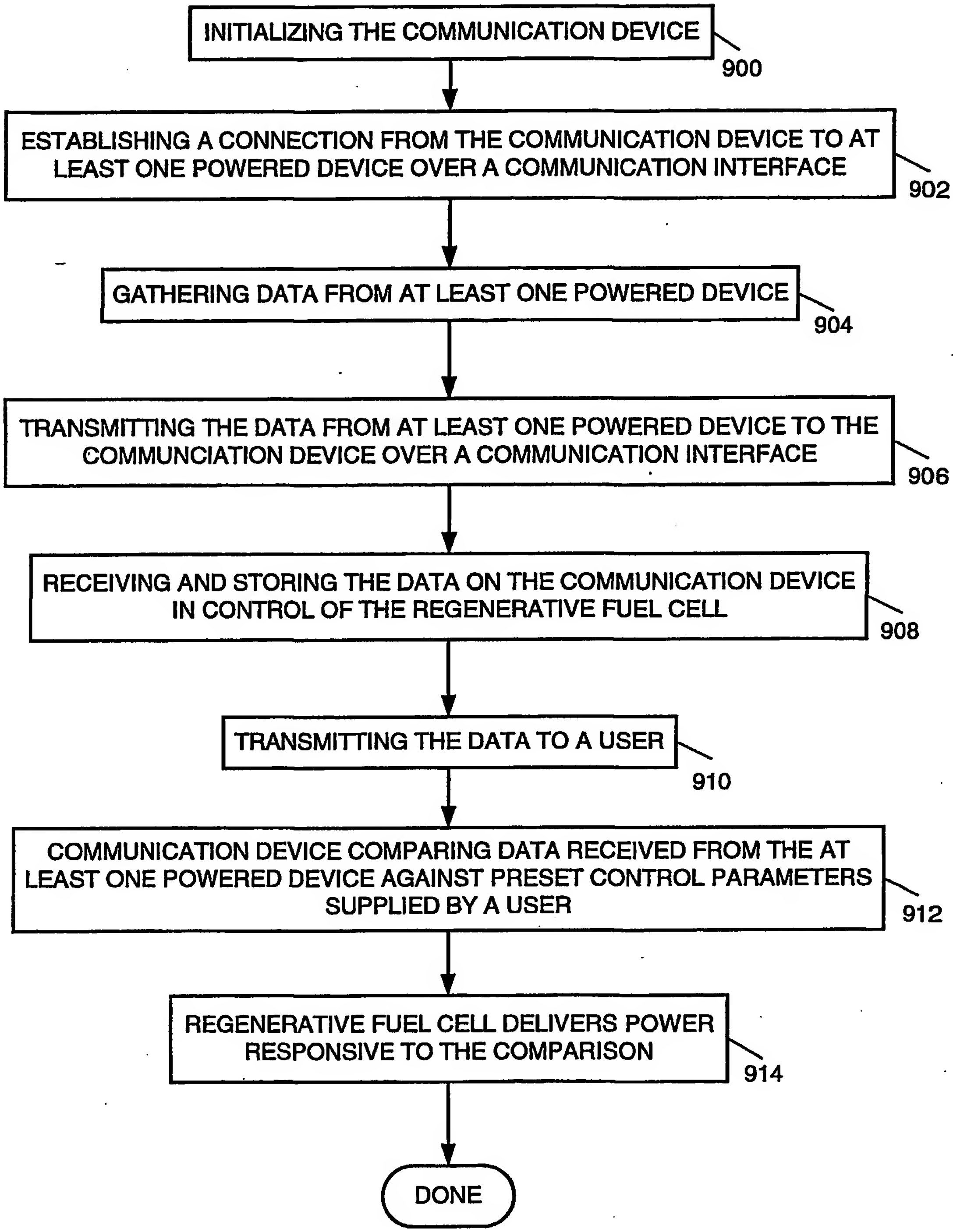
INITIALIZING THE COMMUNICATION DEVICE
900
ESTABLISHING A CONNECTION FROM THE COMMUNICATION DEVICE TO AT LEAST ONE POWERED DEVICE OVER A COMMUNICATION INTERFACE
902
GATHERING DATA FROM AT LEAST ONE POWERED DEVICE
904
TRANSMITTING THE DATA FROM AT LEAST ONE POWERED DEVICE TO THE COMMUNCIATION DEVICE OVER A COMMUNICATION INTERFACE
906
RECEIVING AND STORING THE DATA ON THE COMMUNICATION DEVICE IN CONTROL OF THE REGENERATIVE FUEL CELL
908
TRANSMITTING THE DATA TO A USER
910
COMMUNICATION DEVICE COMPARING DATA RECEIVED FROM THE AT LEAST ONE POWERED DEVICE AGAINST PRESET CONTROL PARAMETERS SUPPLIED BY A USER
912
REGENERATIVE FUEL CELL DELIVERS POWER RESPONSIVE TO THE COMPARISON
914
DONE

FIGURE 9

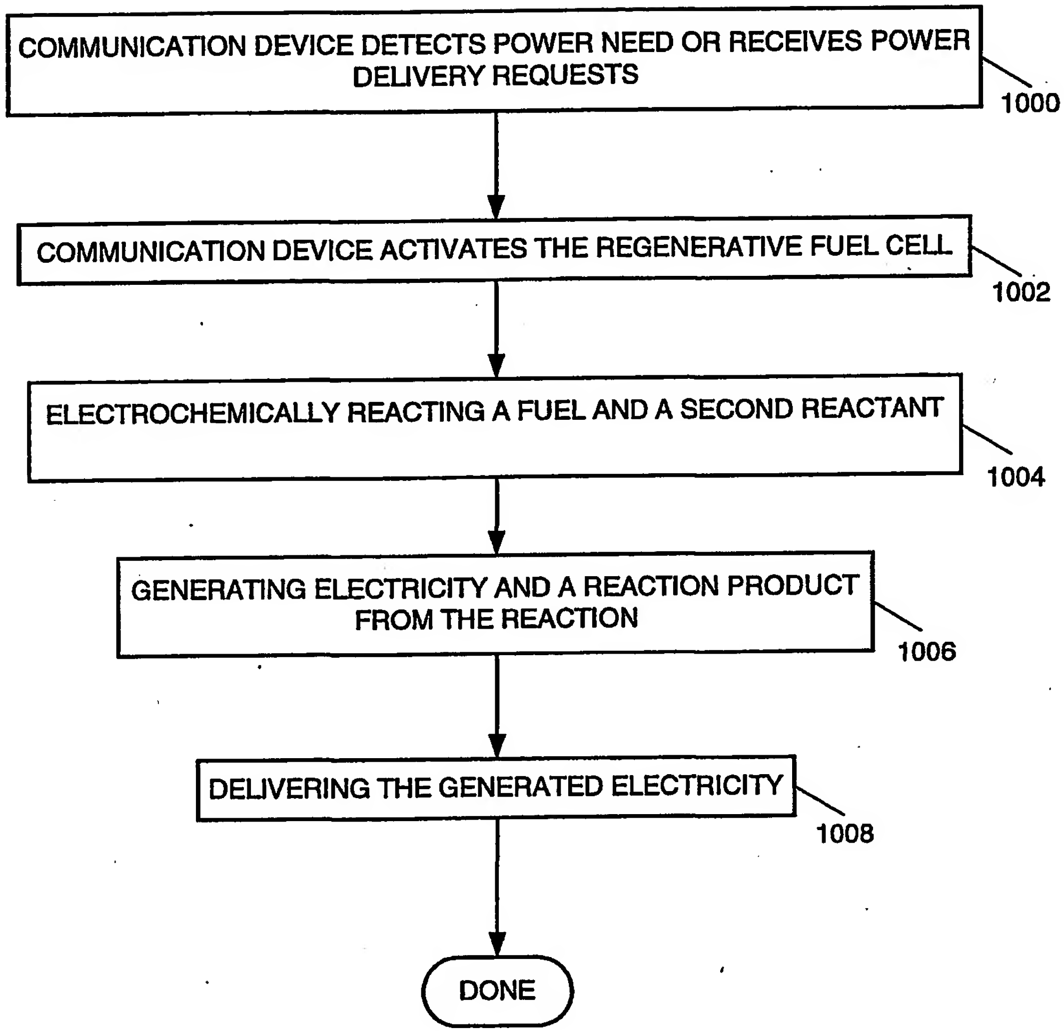
COMMUNICATION DEVICE DETECTS POWER NEED OR RECEIVES POWER DELIVERY REQUESTS
1000
COMMUNICATION DEVICE ACTIVATES THE REGENERATIVE FUEL CELL
1002
ELECTROCHEMICALLY REACTING A FUEL AND A SECOND REACTANT
1004
GENERATING ELECTRICITY AND A REACTION PRODUCT FROM THE REACTION
1006
DELIVERING THE GENERATED ELECTRICITY
1008
DONE

FIGURE 10

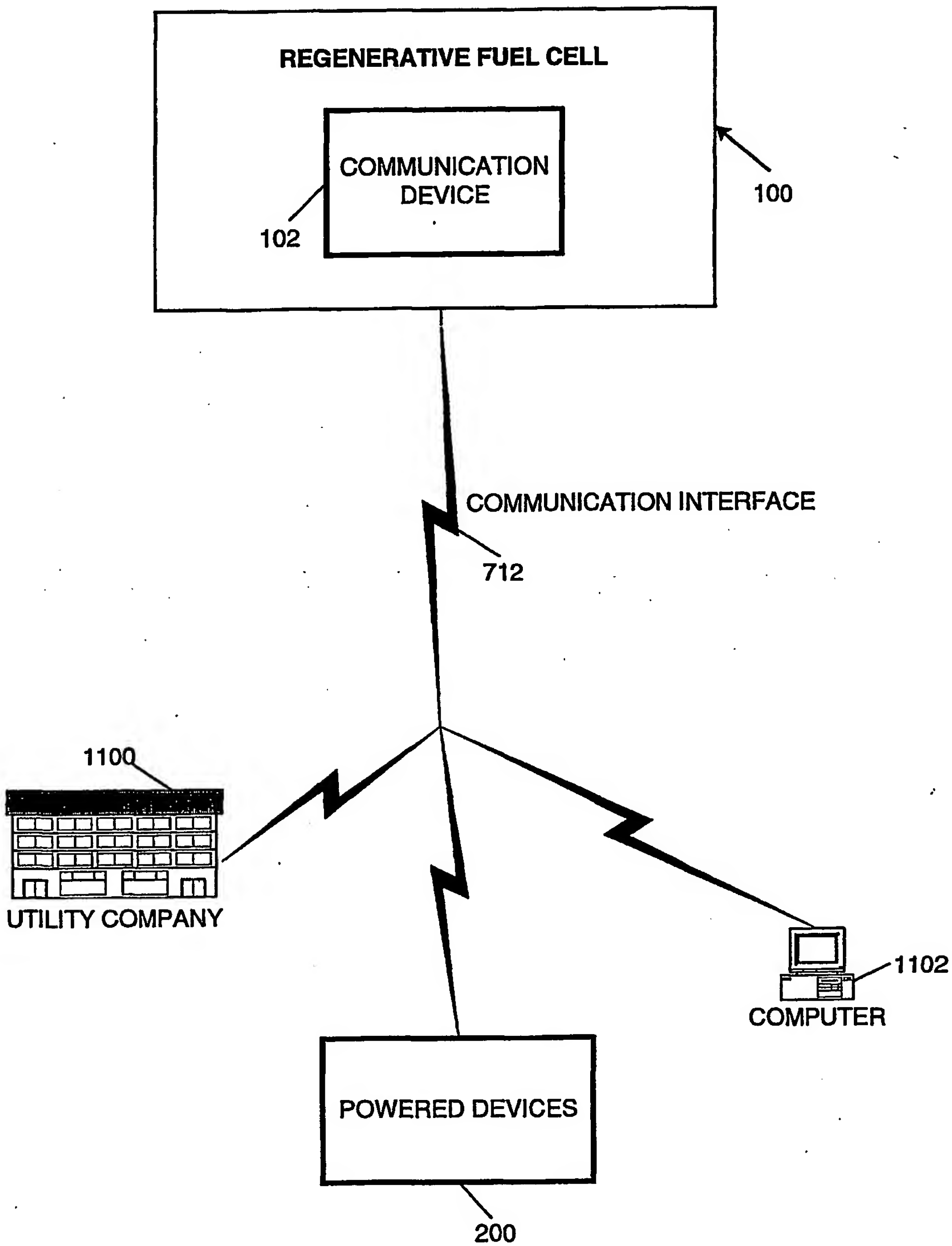
REGENERATIVE FUEL CELL
COMMUNICATION DEVICE
102
100
COMMUNICATION INTERFACE
712
1100
UTILITY COMPANY
1102
COMPUTER
POWERED DEVICES
200

FIGURE 11

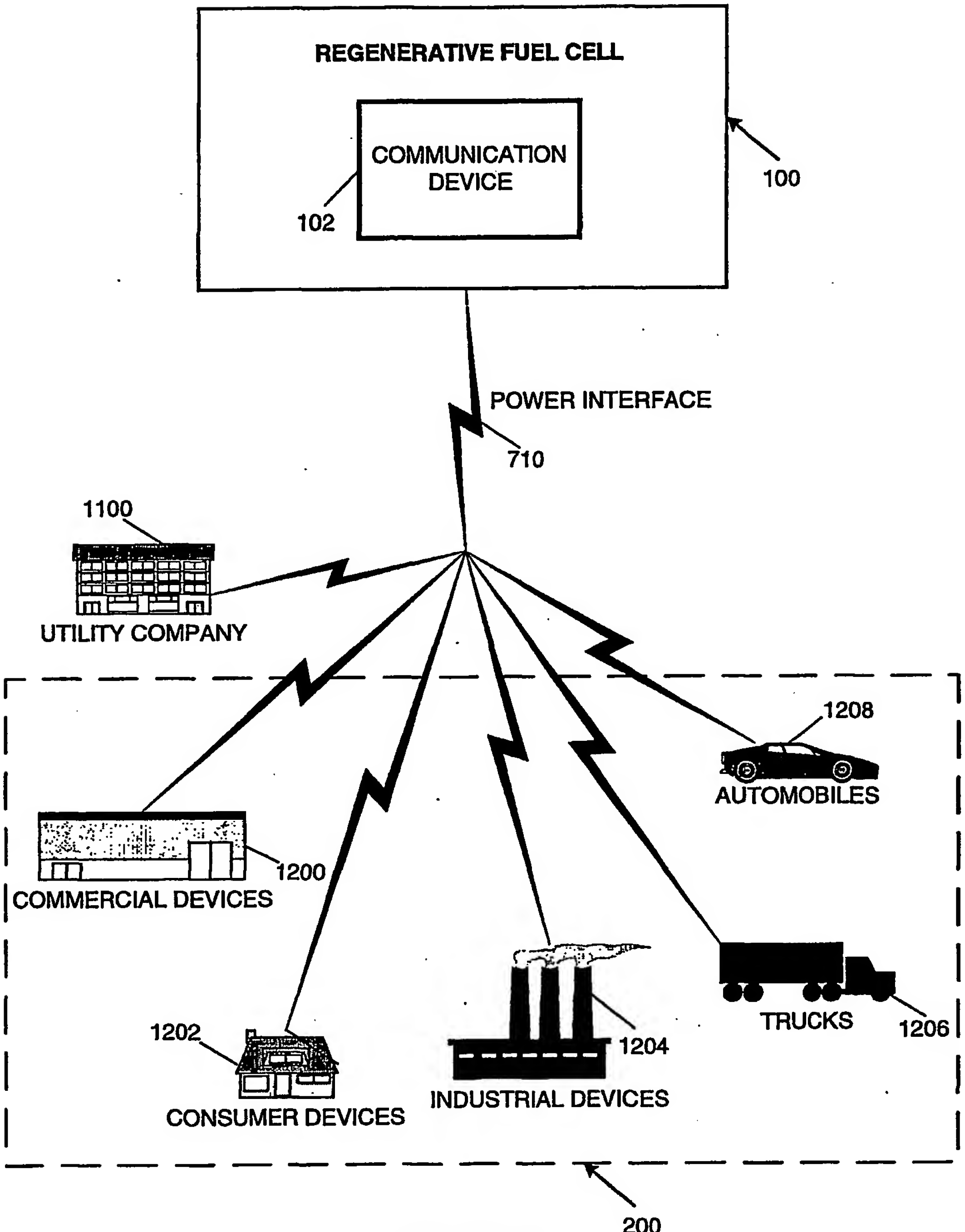
REGENERATIVE FUEL CELL
COMMUNICATION DEVICE
102
100
POWER INTERFACE
710
1100
UTILITY COMPANY
1208
AUTOMOBILES
1200
COMMERCIAL DEVICES
1202
CONSUMER DEVICES
1204
INDUSTRIAL DEVICES
TRUCKS
1206
200

FIGURE 12

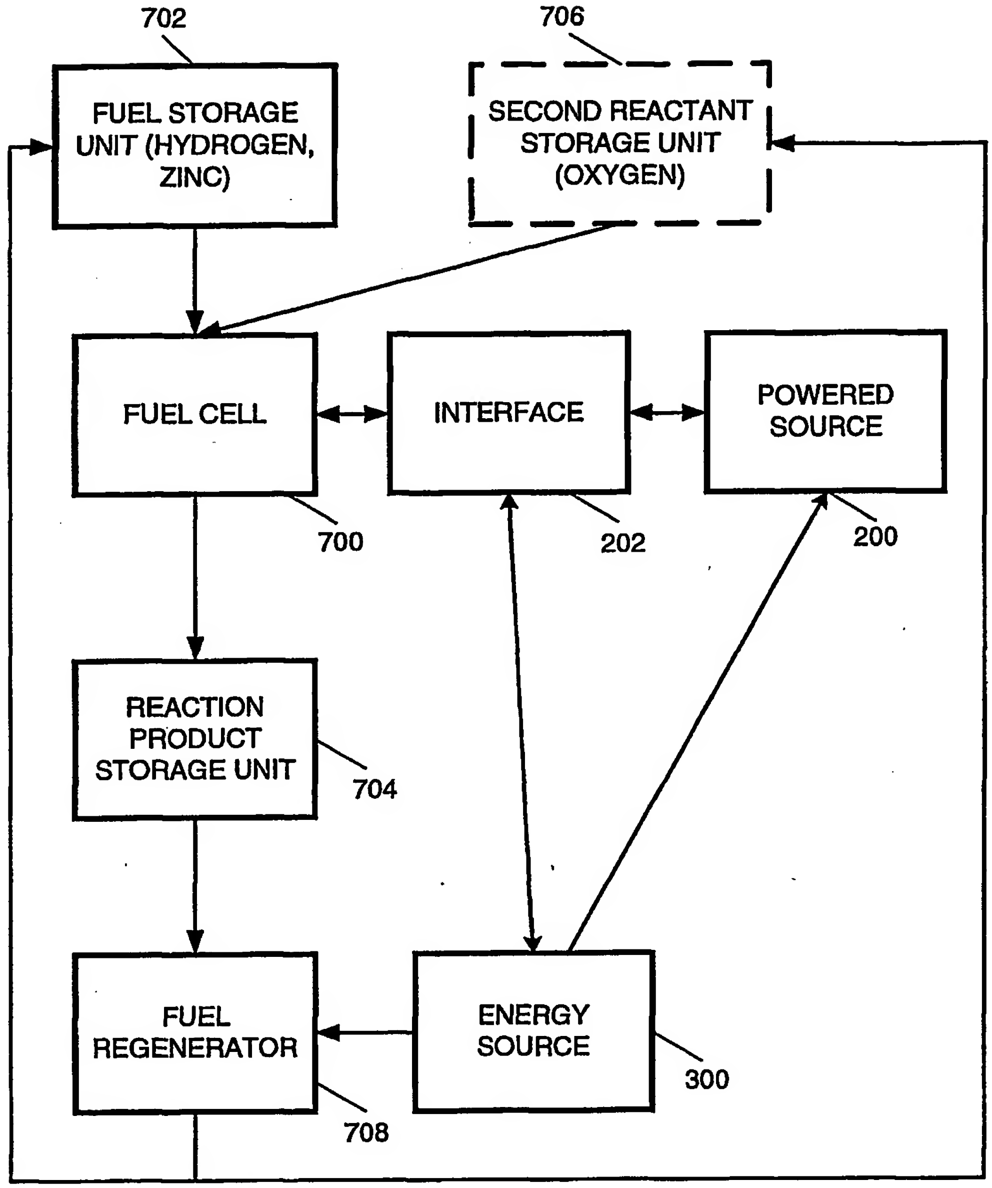
702
706
FUEL STORAGE UNIT (HYDROGEN, ZINC)
SECOND REACTANT STORAGE UNIT (OXYGEN)
FUEL CELL
INTERFACE
POWERED SOURCE
700
202
200
REACTION PRODUCT STORAGE UNIT
704
FUEL REGENERATOR
ENERGY SOURCE
300
708

FIGURE 13

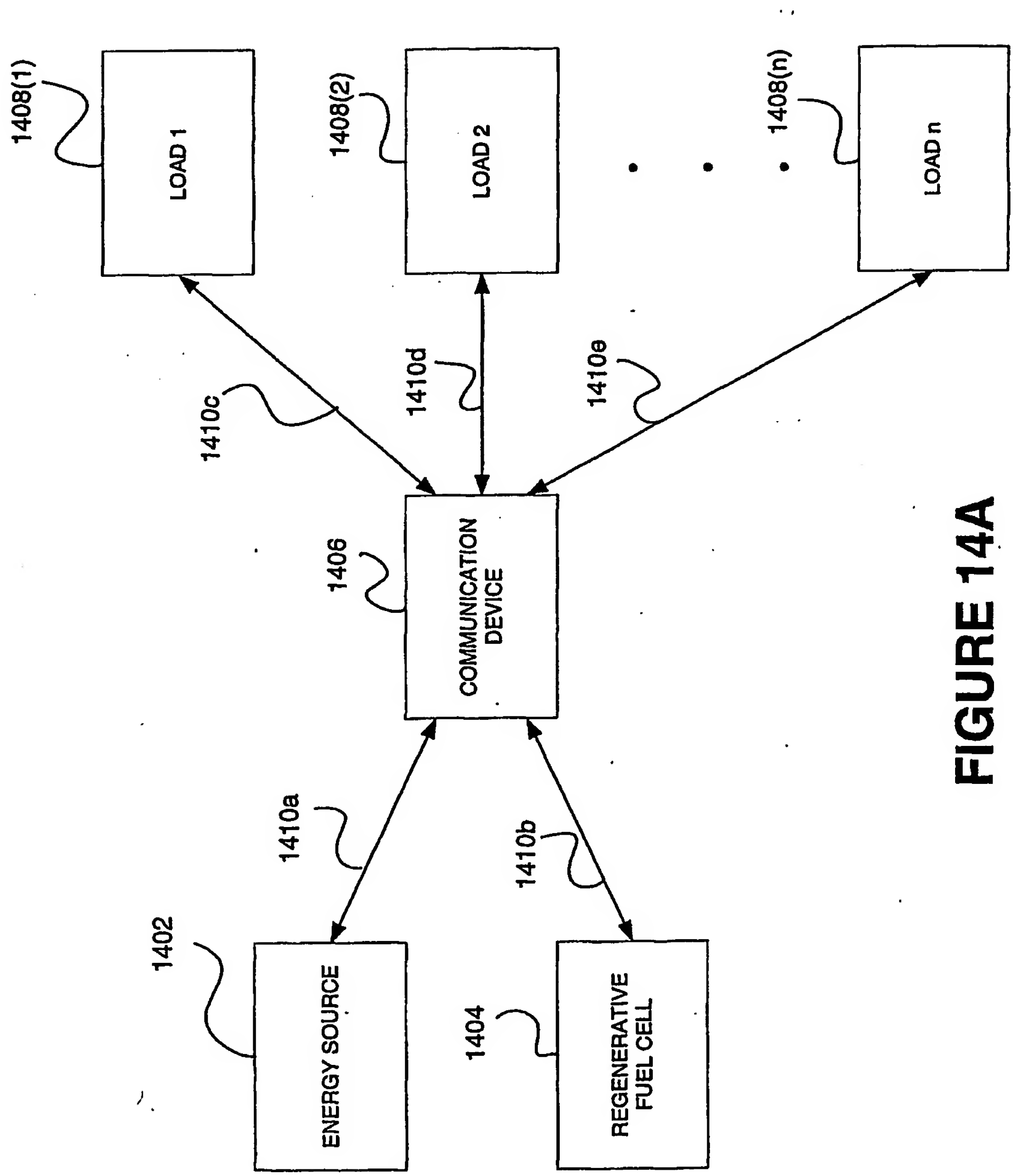
1408(1)
LOAD 1
1408(2)
LOAD 2
1408(n)
LOAD n
1410c
1410d
1410e
1406
COMMUNICATION DEVICE
1410a
1410b
1402
ENERGY SOURCE
1404
REGENERATIVE FUEL CELL

FIGURE 14A

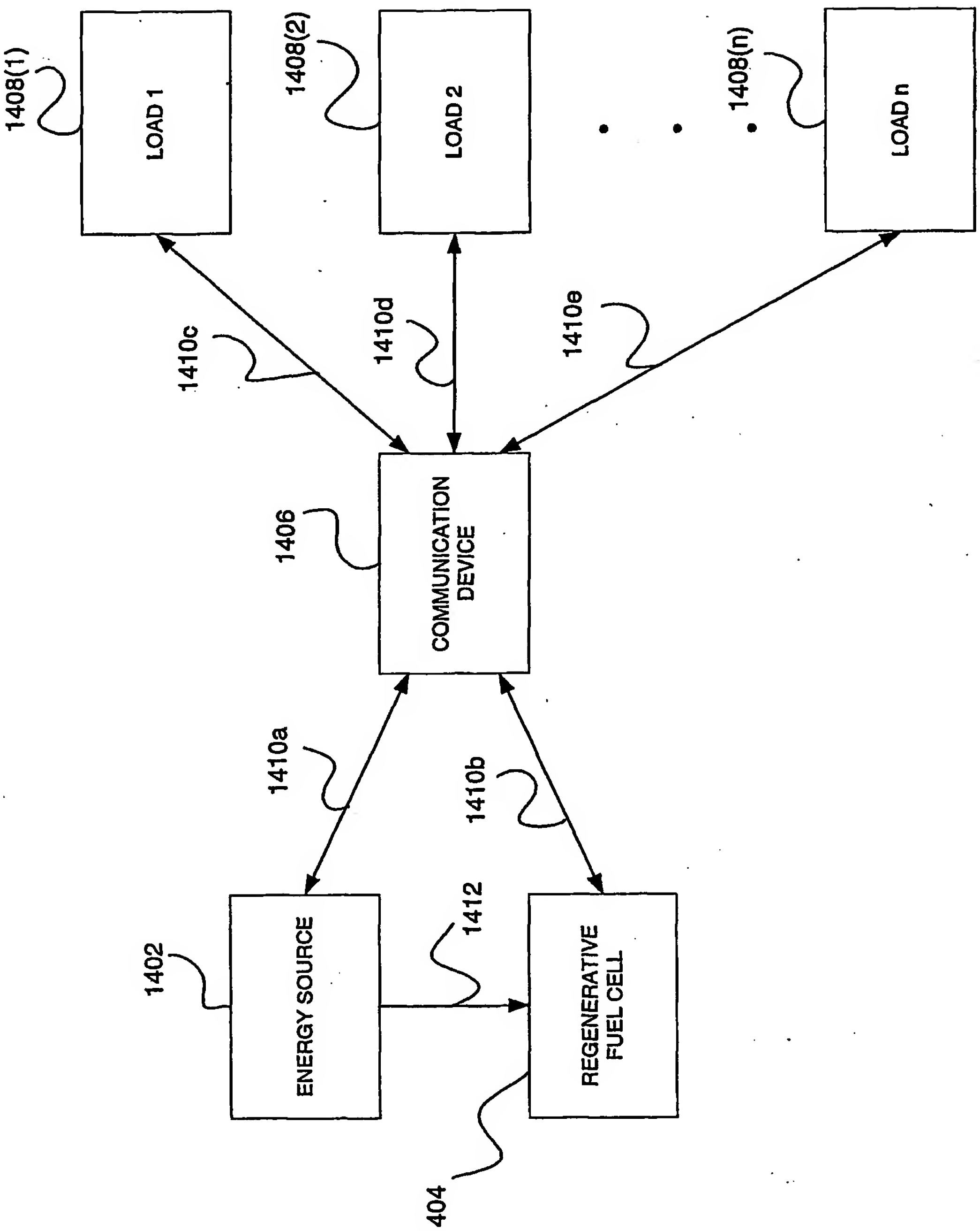
1408(1)
LOAD 1
1408(2)
LOAD 2
1408(n)
LOAD n
1410c
1410d
1410e
1406
COMMUNICATION DEVICE
1410a
1410b
1402
ENERGY SOURCE
1412
REGENERATIVE FUEL CELL
1404

FIGURE 14B

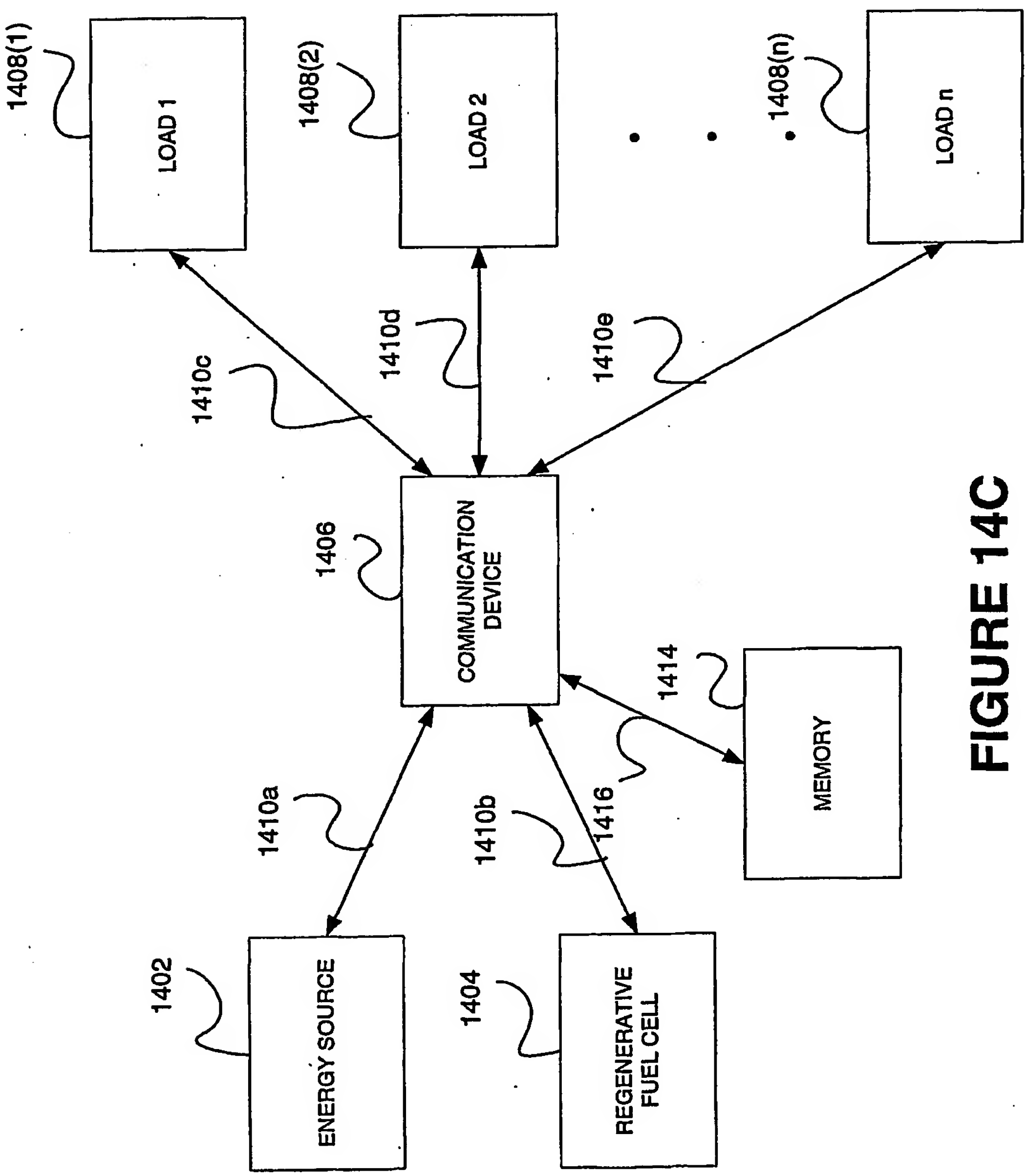
LOAD 1
1408(1)
LOAD 2
1408(2)
LOAD n
1408(n)
1410c
1410d
1410e
COMMUNICATION DEVICE
1406
MEMORY
1414
1416
1410a
1410b
ENERGY SOURCE
1402
REGENERATIVE FUEL CELL
1404

FIGURE 14C

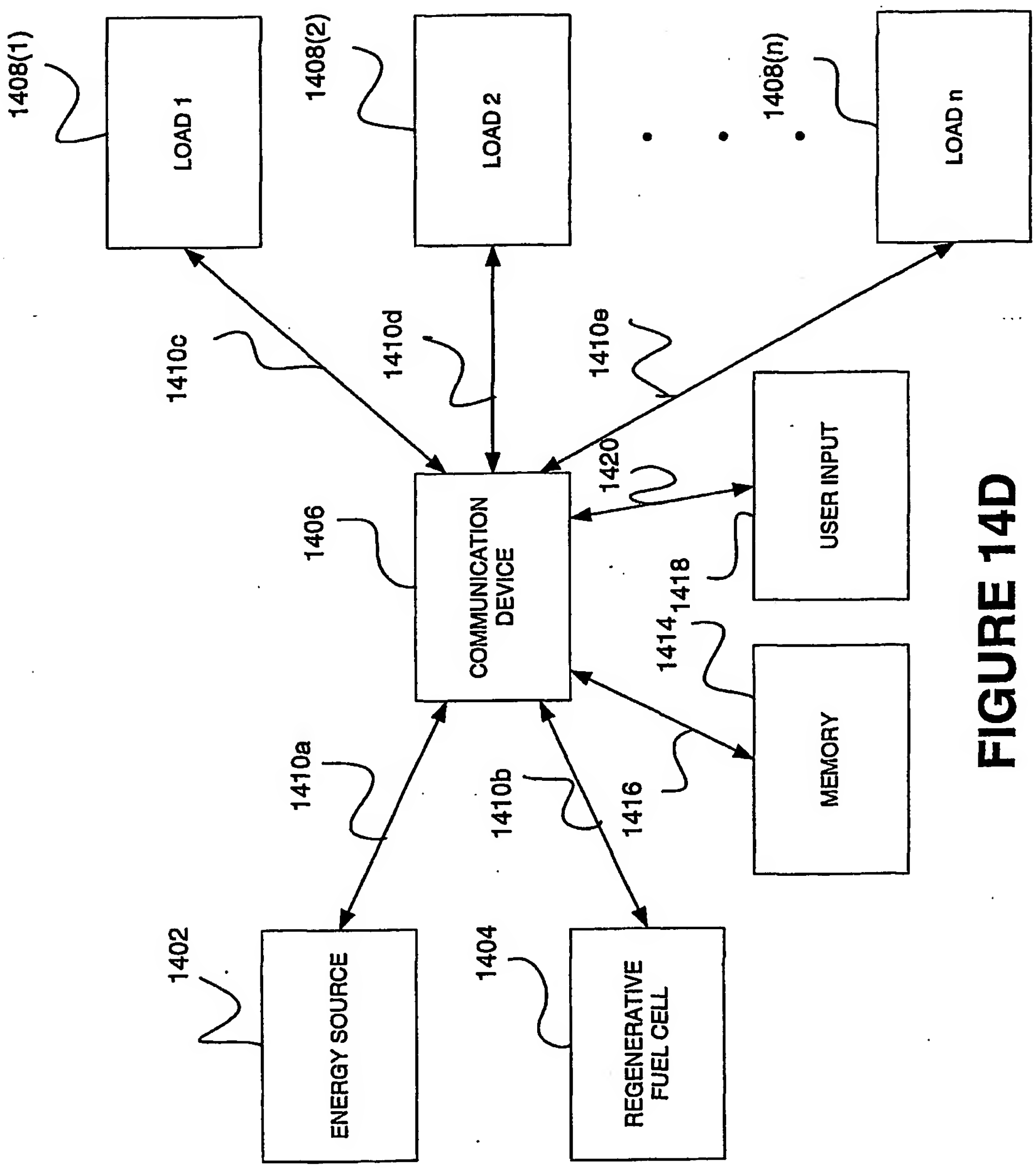
1408(1)
LOAD 1
1408(2)
LOAD 2
1408(n)
LOAD n
1410c
1410d
1410e
1406
COMMUNICATION DEVICE
1420
USER INPUT
1414
1418
MEMORY
1416
1410a
1410b
1402
ENERGY SOURCE
1404
REGENERATIVE FUEL CELL

FIGURE 14D

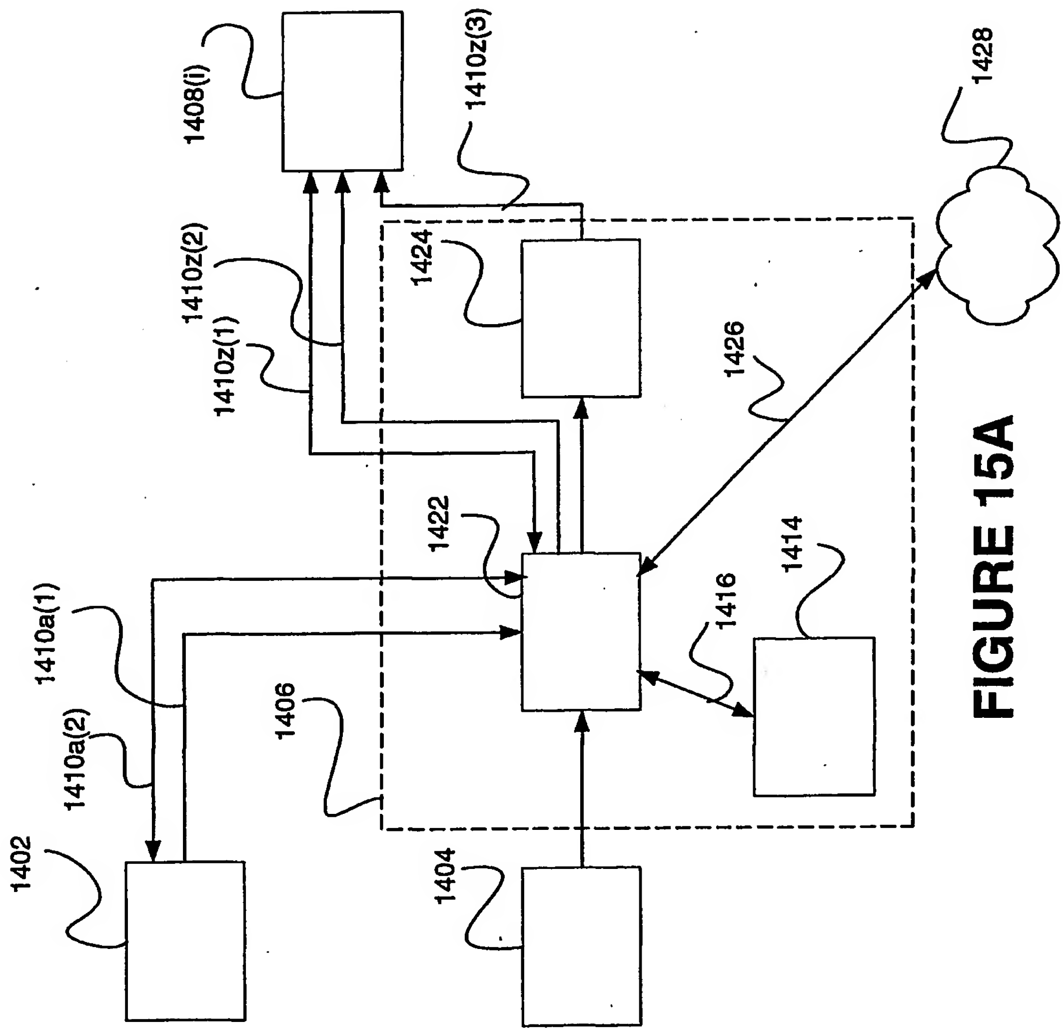
1408(i)
1410z(3)
1428
1424
1410z(2)
1410z(1)
1426
1422
1414
1410a(1)
1416
1406
1410a(2)
1402
1404

FIGURE 15A

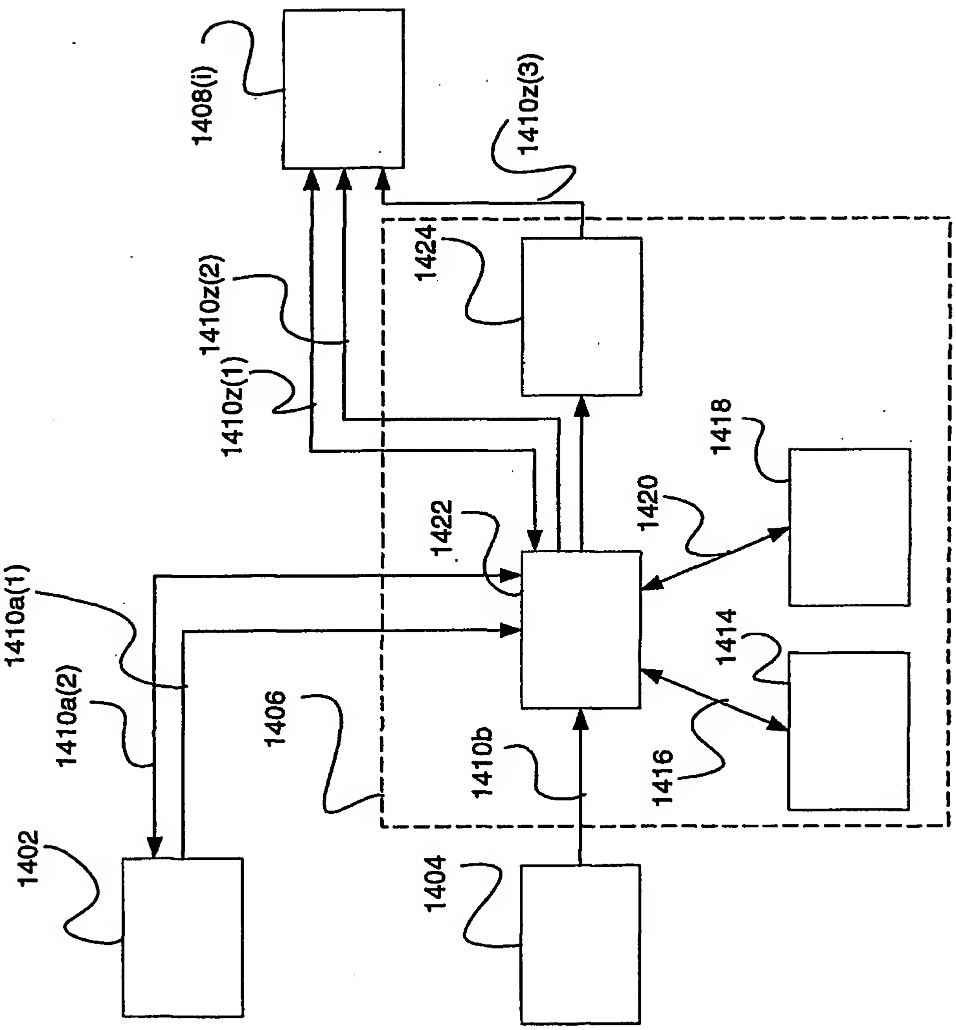
1408(i)
1410z(3)
1424
1410z(2)
1410z(1)
1418
1420
1422
1410a(1)
1410a(2)
1406
1414
1416
1410b
1402
1404

FIGURE 15B

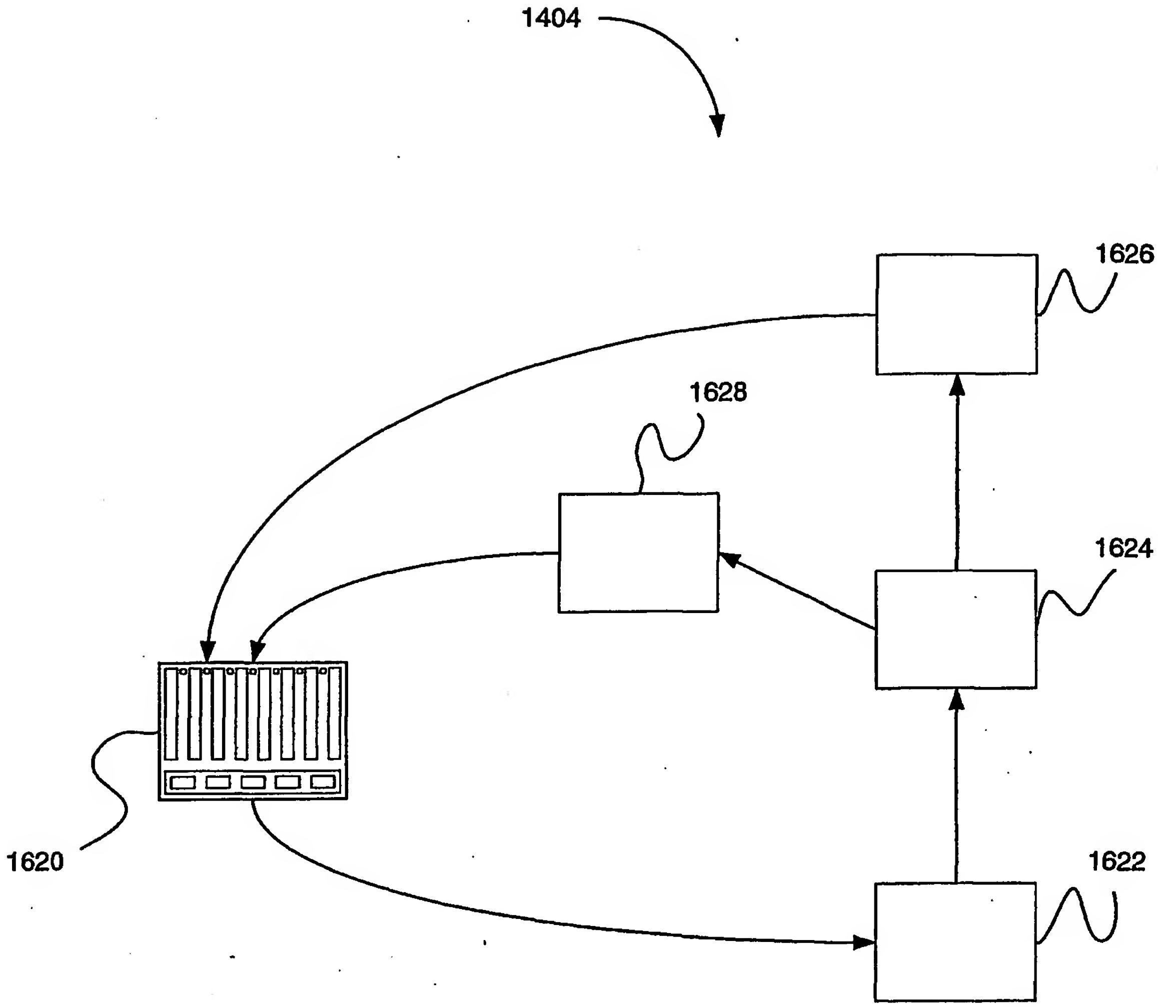

FIGURE 16

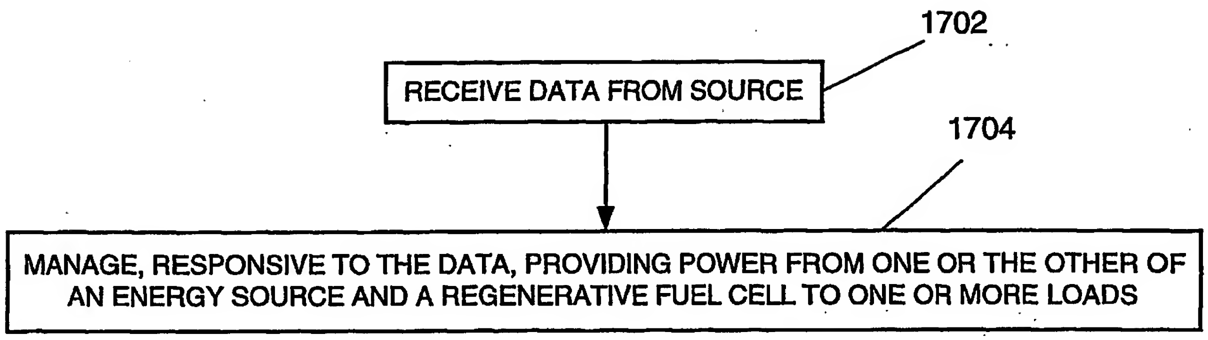
1702
RECEIVE DATA FROM SOURCE
1704
MANAGE, RESPONSIVE TO THE DATA, PROVIDING POWER FROM ONE OR THE OTHER OF AN ENERGY SOURCE AND A REGENERATIVE FUEL CELL TO ONE OR MORE LOADS

FIGURE 17